MONTREAL PROTOCOL
ON SUBSTANCES THAT DEPLETE
THE OZONE LAYER

UNEP

1994 Report of the Technology and Economics Assessment Panel

1995 Assessment

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Montreal Protocol
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MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER

pursuant to
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of the Montreal Protocol;
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Report of the 1994
Technology and Economic Assessment Panel

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Executive Summary

Progress and challenges in the phaseout of ozone depleting substances in developed countries

Developed countries, except for a number of Countries with Economies In Transition (CEIT), are generally on schedule to phase out chlorofluorocarbon (CFC), 1,1,1-trichloroethane, and carbon tetrachloride by January 1, 1996.

The halon phaseout took effect January 1, 1994 with little disruption because the fire protection industry had established global information networks and coordinated halon banks. Halons are in surplus in some countries while in short supply in others. Halon 1301 banking is fully functional in many countries and being organized in others. There is increasing interest in the conservation and banking of halon 1211. Halon banks are important because environmentally acceptable alternatives have not been commercialized for some important fire protection applications.

For CFCs, individual countries with aggressive early phaseout goals are best prepared for their approaching deadlines. The European Union (EU) countries are approaching their internal January 1, 1995 CFC phaseout without alarm. Since the 1995 EU phaseout relies heavily on stockpiling by users, experts wonder whether the transition will be smooth after ozone-depleting substance (ODS) stockpiles are depleted late in 1995/1996. Most other developed countries are on schedule for the January 1, 1996 phaseout with greatest concern for refrigeration and air conditioning servicing and for 1,1,1-trichloroethane solvent use among small and medium-sized industry. The pace of retrofit and replacement has in fact been too slow given the impending production phaseout.

The phaseout is virtually complete in most developed countries for manufacture of automobile air conditioners, refrigerators, foams (except limited use for rigid polyurethane (PU) foams for home appliance insulation), electronics and aerospace products, and non-medical aerosol products.

The most difficult remaining manufacturing challenges are for metered dose inhalers, precision cleaning of sophisticated aerospace equipment (rocket motors, oxygen systems, and deep-space guidance systems), and for laboratory and analytical applications. Many laboratory tests are required by government agencies which currently rely on ODSs. Altering those test requirements will therefore require regulatory change.

A new, and apparently increasing, challenge that needs to be resolved soon is the fraudulent smuggling of newly produced CFC and halon often described as recycled. These shipments could be primarily from Eastern Europe and developing countries where production facilities are still operating. Such smuggling is in contravention of the Protocol, harms the ozone layer, reduces the incentive for phaseout in developed countries, and diverts ODS supplies from developing country users. Measures that could reduce this illegal activity could be designed in a way to certify that quantities and procedures are proper, rather than to prohibit trade. This approach would facilitate continued recycling which often depends on the ability to ship substances to recycle facilities or to markets where recycling is economic.

Implementation of methyl bromide alternatives and substitutes is virtually complete in the Netherlands with the exception of some quarantine uses, and at an advanced stage in countries such as Denmark and Italy that have stringent and immediate domestic controls. Implementation efforts are intensifying in countries like the United States, Canada, and the

European Union that have controls proposed or scheduled for future years. However, despite the clear findings of the Science Assessment, persistent criticism of the science of ozone depletion by advocates of continued methyl bromide use discourages investment in alternatives.

It is documented that between 1981 and 1991 the Netherlands eliminated its use of methyl bromide in soil fumigation through the use of chemicals and non-chemical alternatives such as improved steam sterilization techniques, artificial and natural growth substrates, resistant plant species, crop rotation, and chemical substitutes. Research and demonstration projects are investigating whether these successful strategies will work outside of the Netherlands.

Progress and challenges of developing countries

Many developing countries are making phaseout progress in a variety of application areas, however, some developing countries have actually increased their use of ODSs. ODS solvent use is rapidly decreasing in cases where cooperation exists from multi-national companies and organizations like International Cooperative for Ozone Layer Protection (ICOLP), Japan Electrical Manufacturers' Association (JEMA), Japan Industrial Conference on Ozone Layer Protection (JICOP), and North Atlantic Treaty Organization (NATO) and with strong market incentives. Where private or Multilateral Fund financing has been available progress appears to be underway in refrigeration and in reducing ODS uses in the manufacture of flexible foam, electronics, and aerosol products. The banking of recycled halons in both the developed and developing countries is growing sufficiently to provide maintenance quantities for existing equipment. Developing countries have also made substantial progress in preparing the way for accelerating ODS phaseout. This is being accomplished by institutional strengthening such as establishing National Ozone Units, information exchange, preparation of country programs, and cooperation with the Implementing Agencies over investment project proposals.

The progress achieved by the developing countries is encouraging, but many challenges remain. Progress has not always been made even in cases where ODS substitutes and alternatives are cost effective with rapid payback of investment; such cases could be indicative of a lack of capital for investment. The ODS supply may be uncertain at affordable prices in some regions once developed countries phase out production. Obsolete infrastructure from uses in developed countries may be marketed to developing countries unless discouraged by the Parties. Technology cooperation may lose momentum when developed country partners complete their own phaseout and are less willing to sponsor technical experts. This situation could be improved through continued strengthening of the institutions and personal networking and through further implementation of investment projects under the Multilateral Fund. Developing countries also face challenging decisions on the timing of their ODS phaseouts having regard to the differing implications for costs and environmental consequences.

Progress and challenges of countries with economies in transition (CEIT)

Since the signing of the Montreal Protocol and its London Amendment substantial changes occurred in the countries of the Central and Eastern European region and on the territory of the former Soviet Union. The transition from the "planned economy" political regime to market economies has begun, but it is taking much more time than originally thought and hoped for. As a consequence of the dissolution of the former Soviet Union, as well as the former Yugoslavia, a number of new independent states emerged.

Legislation and institutions

In many of the successor states there is no legislative basis for either ratifying or implementing the Montreal Protocol and there are no institutions and authorities to manage the phaseout of ODSs or even to report consumption data and to establish the baseline consumption level. In a number of states (e.g. the Baltic republics) the accession to the Protocol as amended in London is difficult because these countries are classified as non-Article 5(1) which includes the obligation to contribute to the Multilateral Fund. Fortunately, the Central European states, probably including Slovenia, have both the necessary legislation and administrative capabilities to govern the phaseout of ODSs.

Status of countries with economies in transition

All states of the Central and Eastern European region as well as Commonwealth of Independent States (CIS) states are struggling with the difficulties of the transition from a planned economy to market economy, world-wide recession, market discrimination and exclusion, high inflation rates and chronic lack of capital, even for investments with short pay-out time. Their resources are mostly inadequate for a timely ODS phaseout. The phaseout of the production in the Russian Federation is an additional problem. A substantial part of the reduction of the consumption of ODSs in the Central European states has been a consequence of the decrease in industrial output due to the factors referred to earlier, and only partly as a result of actual phaseout activities/investments.

It seems inevitable that non-compliance will occur in several states. The disruption to industry caused by political changes, coupled with lack of finance and appropriate infrastructure means that transition to non-ODS will not occur by 1996.

The Technology and Economic Assessment Panel (TEAP) wishes to draw the attention of the Parties to the problems of countries with economies in transition, which did not exist when the Montreal Protocol and its London Amendment were signed.

In the 1995 March TEAP Report a more detailed description of the problems and possible approaches to solve those problems will be presented.

The current importance of Hydrochlorofluorocarbons (HCFCs) to the CFC phaseout

HCFCs remain critical for meeting the near-term CFC phaseout goals. They are less important for new equipment available in the mid and long-term period. HCFCs are currently necessary for certain new refrigeration and air conditioning applications, for servicing already installed HCFC equipment, for some rigid thermal insulating and automotive safety foam products, and for several important small uses such as sterilization, where some existing equipment cannot be converted to non-ODS alternatives.

The Parties had in 1993 requested by Decision V/8 that the TEAP and its Technical Options Committees (TOCs) investigate alternatives and substitutes to HCFCs with elaboration and report its findings in November 1994. They also requested investigation of potential control strategies for HCFCs and methyl bromide for developing countries. However, at the sixth Meeting of the Parties, these requests were updated with Decision VI/13, which requested an evaluation of feasibility and implications of the available alternatives and substitutes to HCFCs and methyl bromide. As a result of the 1994 request by the Parties, the TEAP will make summary of alternatives and substitutes to HCFCs and methyl bromide in this Report but the March 1995 Report will be more detailed and will respond to both Decision V/8, V/19, and VI/13.

The TEAP has already concluded that it is technically and economically feasible to reduce the HCFC cap due to the rapid development of alternatives and substitutes to HCFCs. Furthermore, if the Essential Use Process were applied to HCFCs, it could facilitate an early HCFC phaseout for new applications (while continuing to depend principally on the allowable production of controlled substances until 2030 for servicing) by providing the possibility that critical HCFC uses could be authorized by the Parties. The expanded 1995 evaluation will further elaborate the technical and economic feasibility of reducing the HCFC cap and/or shortening the "tail" of use in developed countries at reduced levels. If possible, the TEAP will investigate several scenarios such as "business as usual" with aggressive marketing and exaggerated new uses versus a "maximum feasible protection strategy" with balanced incentives for rapid CFC elimination and controlled HCFC dependence for new equipment.

The TEAP will also describe the history of technical development in applications where HCFCs were the first feasible alternatives to CFCs but may no longer be required. In some cases the investigation of HCFC substitutes to CFCs was a necessary intermediate step that later enabled the introduction of non-ODS alternatives. This discussion will also explore the consequences of requiring new investment by the industry leaders who took early actions to protect the ozone layer by switching to HCFCs from CFCs when no other alternatives were available.

The 1994 essential use process

The 1994 Essential Use Process was successful despite problems of unclear instructions, incomplete applications, and difficult communication. These problems are being resolved with the publication of the Essential Use Handbook, the experience gained in the 1994 Assessment, and through other efforts.

In 1994 the TEAP and its TOCs undertook a cooperative and collaborative review of essential use nominations on a challenging time-table and without budget. In many cases, the volunteer experts identified suitable alternatives or substitutes or helped guide applicants through rapid identification and development.

The Parties generally agreed with the TEAP and TOC consensus conclusions but chose to grant the initial exemptions for a maximum of two years.

In the case of Metered-Dose Inhalers (MDIs) the Panel and the Aerosol Products TOC had recommended initial exemptions for all MDI applications but the Parties decided to only grant exemption for oral inhaled drugs for asthma and Chronic Obstructive Pulmonary Disease (COPD) and for a single category of anti-cancer medicine (leuprolide) which is proposed--but not yet commercialized--by a single manufacturer. The Panel and TOC had recommended an initial exemption for the broader category of drugs based on the lack of detailed information provided which is necessary to ascertain the essentiality of non-pulmonary drug use. The Panel and TOC will further investigate these issues in the March 1995 Report and provide additional guidance for the Parties. However, micro-management of such issues by either the Panel or the Parties may not further protect the ozone layer if it distracts work from more significant uses and topics. It will be particularly important to ensure that nominations follow the evaluation process and meet requirements of essentiality decided by the Parties.

Sector Progress: Non-Medical Aerosol Products

A significant reduction in CFC use for non-medical aerosol products has occurred since 1986 with current global use less than 80,000 tonnes.

A large majority of non-medical aerosol products use hydrocarbon propellants. Other alternative flammable propellants are dimethyl ether and hydrofluorocarbon (HFC) 152a. Non-flammable alternatives include CO_2, N_2, HFC-134a, and HFC-227. HCFCs have limited and temporary applications that are expected to decrease significantly over the next few years. Non-propellant alternatives such as pumps and roll-ons can also be used to apply or administer some products.

Despite this global progress, CFCs are still used in significant volume for non-medical products in some developing countries and in countries with economies in transition. In some countries serious problems exist in obtaining quality hydrocarbon propellant feedstock.

Sector Progress: Medical Aerosol Products

Metered Dose Inhalers (MDIs) will continue to use CFCs under terms of the Essential Use Decision. CFCs are most difficult to eliminate for treatment of pulmonary diseases. These diseases are rapidly increasing world wide and inhaled medications are increasingly recommended for the treatment of asthma and Chronic Obstructive Pulmonary Disease (COPD). Inhaled medications include MDIs and Dry Powder Inhalers (DPIs). DPIs are suitable for some patients but are not adequate for children, elderly or very sick patients who cannot strongly inhale. In 1992, approximately 15% of inhaled medicines were DPIs.

HFC-134a and HFC-227 appear to be suitable substitutes for CFCs in MDIs. However, these products will not be commercialized until 1996 due to extensive toxicological and clinical studies necessary to ensure safety. It is envisioned that the transition will occur in the late 1990s.

Sector Progress: Sterilization

Ethylene oxide (EO) is particularly useful for sterilizing heat and moisture sensitive products. It can be diluted with 88% CFC-12 to inert its flammability. EO can also be inerted with CO_2 or HCFCs or can be used in explosion-proof facilities. It is technically feasible to phaseout CFC-12 in developed countries by 1995. The high cost of HCFC drop-in replacements and lack of access to technology and training could increase the time scale of phaseout in developing countries.

Sector Progress: Miscellaneous Uses

There are applications such as tobacco expansion, food freezants, linear accelerators, thermostats, and thermometers which use CFCs, globally in small quantities. All should be able to be converted to the use of alternatives or other technologies that do not use CFCs.

Sector Progress: Carbon tetrachloride

Carbon tetrachloride use as a feedstock is allowed to continue after the phaseout and can continue in 1996 as a process agent while the TEAP investigates uses and alternatives.

Carbon tetrachloride is still used in large amounts as a solvent in Eastern Europe and Asia despite its toxicity. Alternatives to this dangerous application are widely available.

Sector Progress: Rigid and Flexible Foams

In 1993 the foam plastics industry reduced CFC consumption by 50% since 1986, despite a 45% market growth rate over that period. The CFC phaseout for developing countries is technically feasible around the year 2000 provided that Multilateral Fund projects are implemented without delay.

Zero ozone depletion potential (ODP) alternatives are the substitutes of choice in many applications, for example, in packaging, in cushioning and in certain rigid thermal insulation foams. The main zero-ODP solutions still to be proven are liquid HFCs. In addition, broader qualification and regulatory approval of hydrocarbons is also required. This situation is likely to be resolved around the year 2000. Once zero ODP solutions have been proven, and are commercially available, the implementation can be relatively rapid (3-5 years) for foam manufacturing in developed countries.

In several markets and for certain applications HCFCs are necessary for rigid thermal insulating and automotive integral skin foams (used for padding) until zero ODP solutions are proven to have similar performance including high energy efficiency and properties required for safety.

Full recovery and recycling of CFCs from the existing stock of foam is logistically and technically difficult.

Sector Progress: Halons

Halon production in all developed countries, except for the Russian Federation, phased out on January 1, 1994. There are a few fire/explosion risk scenarios for which current fire protection technology cannot provide adequate protection without the use of halons or halon-like replacement extinguishants. These risk scenarios involve an unacceptable threat to human life, the environment, or national security, or an unacceptable impairment of the ability to provide essential services to society. With proper management, the future needs of the majority of these risk scenarios can be satisfied by redeployment of existing, banked halons until such time, beyond the turn of the century, as the bank expires and alternatives become available.

Application-specific replacement extinguishing agents and alternative technologies are now commercially available, although environmental and toxicological concerns have limited the acceptability of some replacements. The primary environmental factors to be considered for these agents are ODP, global warming potential (GWP), and atmospheric lifetime. Comparison of halocarbon replacements with other alternatives should be based on consideration of the environmental impact of each alternative.

While GWP and atmospheric lifetime are potentially important environmental factors of halon replacement agents, the objective of replacing halons with non-ozone depleting substances is paramount to the goals of the Protocol. Therefore, the use of controlled, non-zero ODP compounds, including HCFCs and hydrobromofluorocarbons (HBFCs), as halon replacements is not a wise decision if it can be avoided, especially for Article 5(1) countries.

Recognizing persuasive environmental concerns, the Halons Technical Options Committee does not endorse the widespread use of HCFCs and HBFCs or perfluorinated carbons (PFCs), in preference to other, effective, new or existing technological alternatives for fire protection. The use of any synthetic compound that accumulates in the atmosphere carries some potential risk with regard to atmospheric equilibrium changes, with consequences to long-term availability of the compound and subsequent support for installed fire protection systems.

International cooperation on the movement of recycled halons facilitates access to a bigger market for the sale or purchase of halons, and provides the ability to recharge critical halon systems, such as on board ships and aircraft, while in a foreign territory. It is therefore important that the Parties ensure that national regulations that were implemented to restrict imports and exports of newly produced halons do not impede the international trade in recycled halons or their premature destruction.

Sector Progress: Methyl Bromide

Methyl bromide is principally used as a fumigant, controlling a wide spectrum of pests, including pathogens, insects and nematodes. It has sufficient phytotoxicity to control many weeds and seeds in soils.

Of the 1992 global sale of methyl bromide of 75,625 tonnes, 3.2% was used as a feedstock for chemical synthesis. It is estimated that the remainder was used for soil treatment (70%); fumigation of durables (16%) fumigation of perishables (8.0%), and fumigation of structures and transportation (2.7)%. The proportions for 1991, the base year, are similar to those for 1992. The Methyl Bromide Technical Options Committee (MBTOC) noted that, in the absence of controls some developing countries expect to expand uses of methyl bromide substantially. Global consumption, excluding feedstock uses, has increased about 3,700 tonnes per year since 1984.

Under the current usages pattern, the proportions of applied methyl bromide emitted eventually to atmosphere globally were estimated by MBTOC to be 30-85%, 48-88%, 85-95% and 90-95% of applied dosage for soil, durables, perishables and structural treatments, respectively. These figures, weighted for proportion of use and particular treatments, correspond to a range of 47-81% overall emission from agricultural and related uses (34,000-59,000 tonnes, based on 1992 sales data).

There is active research into the development of recovery and recycling equipment for methyl bromide. A few special examples of recovery equipment are in use and it is anticipated that prototype systems capable of recycling recaptured gas for some use areas will be evaluated by the end of 1995. Most development work is directed at recovery from enclosures used for structure or commodity fumigation (about 24% of global production). Some preliminary work on recovery for soil fumigation is in progress.

If recovery is to be recognized as an acceptable method of reducing methyl bromide emissions to the atmosphere, it will be necessary to set specifications on aspects of fumigation, such as equipment efficiency and tolerable levels for emissions.

There is no single alternative to methyl bromide in all of its wide range uses. However, technically, alternatives do already exist for a number of current applications.

MBTOC estimates that by using known technology it is technically possible for Parties operating under Article 2 to significantly reduce usage of methyl bromide. Estimates of the magnitude of the reduction and its time scale varied widely amongst MBTOC members.

Opinions ranged from a reduction of 50% feasible by 1998, to decreases of only a few percent by 2001. Reductions should be achievable through a combination of implementing alternatives and use of better containment technology, together with longer exposure times and lower dosages for methyl bromide treatment, particularly in soil fumigation. Achievement of such reductions may entail use of some alternatives which may have potential to cause environmental and health effects. Some alternatives, notably those leading to residues in products, while technically effective, may not be acceptable to regulatory authorities, markets, or end users.

It was noted that there are specific constraints on rapid implementation of some alternatives associated with the time taken to gain registration and regulatory acceptance of some procedures. The problem is particularly acute in some cases relating to treatment of exports to meet quarantine standards where extensive trials and protracted bilateral negotiations may be required.

While alternatives are available for the majority of current uses, the MBTOC did not identify technically feasible alternatives, either currently available or at an advanced stage of development, for less than 10% of 1991 methyl bromide use.

Developing countries currently use about 18% of methyl bromide produced globally for agricultural and related uses. The main uses are for soil fumigation (about 70% of total) and disinfestation of durables (about 20%).

Soil fumigation is mainly carried out in Article 5(1) countries for pest and disease control in the production and export of certain high value cash crops (e.g., tobacco, cut flowers, strawberries, vegetables). It is used particularly for fumigation of nursery and seed beds. Methyl bromide is not used during production of staple foodstuffs. Where used on durables, the main application is the protection of local stocks of food grains and for disinfestation of imported and exported cereal grains and timber.

Potential trade restrictions relating to methyl bromide use are of great concern to those Article 5(1) countries dependent on certain exports now produced with the aid of methyl bromide. Such restrictions, which could be applied by developed, importing countries and regions, as a result of their own or international restriction on methyl bromide, are seen as an issue of substantial importance. They could nullify the effect of any grace period.

Sector Progress: Refrigeration and Air Conditioning (AC)

In 1993, the global refrigeration, air conditioning and heat pumps sector in developed countries reduced from 1986 levels its CFC consumption by about 35%, despite a 30% market growth. However progress was not achieved in every region. The European Union actually increased its use while the United States decreased use by 50%.

Zero-ODP substitutes (HFC, HFC blends, ammonia, and hydrocarbons) are the substitutes-of-choice in many new equipment applications. Hydrocarbons have made a remarkable penetration in the domestic refrigeration market, partly because of their support and promotion by Non-Governmental Organizations (NGOs).

The largest share of zero-ODP substitutes is the HFC blends with increasing use of ammonia and hydrocarbons. Hydrocarbons are currently used in about 5% of new refrigerators but are expected to increase to 30% over the next 3-5 years for application in both developed and developing countries. In large systems, ammonia is expected to dominate but with substantial use of HFC and HFC-based blends. Ammonia is not available now for smaller units, but product development is underway.

In servicing a variety of refrigeration and AC equipment, including retrofits, the use of HCFC or HCFC based blends is currently necessary. No non-HCFC substitute has been identified so far for small (HCFC-22), and very large sized commercial and industrial chiller systems. However, the HCFC chemicals will be increasingly replaced in new refrigeration and air conditioning equipment by other chemicals such as HFC mixtures or blends. HFC retrofits are becoming feasible with increased application anticipated in 1995-1997. HCFC use in refrigeration is expected to stabilize at 1989 levels in 1995 and 1996 and then decrease from 1996 to 2000.

The automotive sector in all developed countries and in some developing countries has changed from CFC-12 to HFC-134a for all new equipment. Retrofits are increasingly available and being implemented in developed countries, but usually at higher cost than servicing with CFCs.

Recycling and recovery is most successful in developed countries with high CFC costs and where regulation is in place. Without such incentives, CFC conservation is likely to be minimal. In developing countries it can often be cost-effective to improve maintenance and to recycle from large systems.

Sector Progress: Solvents

Most developed country suppliers and consumers of ozone depleting solvents are halting production and use earlier than mandated or expected. A few enterprises have made unwise first choices of alternatives and substitutes and are changing to better options. However, significant problems exist in the European Union (EU) where many companies began their investments too late and may not be able to halt their use prior to the January 1, 1995 EU phaseout of production.

Furthermore, some large companies in developed countries may have been over-confident that their uses would qualify as essential and consequently may not have allowed enough time for a smooth transition. Varying sizes of enterprises, but especially small and medium-sized enterprises are identified in many developed countries as possibly being unaware, unprepared, and financially unable to make necessary investments in time to avoid chemical shortages and price increases that could jeopardize their businesses.

Procrastination in implementing alternatives and substitutes could lead to significant price increases for stockpiled and recycled ODSs manufactured prior to the phaseout. Dramatic price increases could stimulate illegal markets in imported solvents. In the immediate future, shortages of ODS solvents could cause companies to switch to chlorinated and/or HCFC solvents, if allowed, because these solvents can often be used in existing equipment.

In January 1994 the North Atlantic Treaty Organization (NATO) held its 2nd international conference on "The Role of the Military in Protecting the Ozone Layer". NATO members reported that they are meeting or exceeding the production phaseout goals of the Montreal Protocol and EU members reported that they are meeting their more stringent goals. Part of the reason for this progress has been the leadership of policy makers in some ministries of defence who realized that global environmental protection is part of national security and also recognized that they cannot continue to depend on chemicals that will be unavailable or increasingly expensive.

The Solvents Committee cautions that manufacturers may eliminate ODSs from products without notifying customers. There is the possibility that the manufacturer may not appreciate that their product is used in a particular application where the ozone-depleting substance provided a necessary performance characteristic that is not duplicated by the reformulated product. Use of such reformulated materials and products under these circumstances could be costly or dangerous to life and health. The solution is to better communicate changes in product ingredients and to cooperate on performance testing of the new products.

In some cases technology cooperation with developing countries has already been highly successful or has prepared countries to take prompt action once incentives and financing are in place. Examples include Mexico, Thailand, Turkey, and Malaysia. An important conclusion from investigations of solvent use in developing countries is that enterprises must be motivated and prepared to accept new technology. This motivation can result from government regulation, a clearly articulated industry phaseout strategy, price increases, product shortages, or supply uncertainty for ozone-depleting substances. Some technology cooperation efforts have been prematurely attempted in countries where enterprises and national governments were not prepared, and as a consequence little actual investment progress has been made.

Solvent HCFC

Few large scale current uses of HCFCs has been reported for solvents, coatings, or adhesives. In the near term HCFCs may be necessary as transition substances in some limited and unique applications. In countries where HCFCs are prohibited, enterprises may, in certain specific cases, select perfluorinated carbons (PFCs) as an adjunct to specialized cleaning systems. PFCs have extremely long atmospheric lifetimes and have potent global warming potentials (GWPs) and should therefore be avoided where possible.

It is estimated that HCFC-141b and HCFC-225 together will not replace more than 1 percent of global CFC-113 uses unless HCFC-225 becomes a substitute for CFC-113 in dry cleaning, which could increase use to approximately 5 percent.

Progress in eliminating ODS from rocket motors

Ozone Depleting Substances (ODSs) have been routinely used globally for decades in the manufacture of space launch vehicle solid rocket motors (SRMs). The primarily ODS solvents used are 1,1,1-trichloroethane (TCA or methyl chloroform) and CFC-113.

Since 1989, the four US manufacturers of large SRMs have eliminated over 1.6 million pounds of ODS use per year. Current (1994) ODS usage is less than 48 percent of the use in 1989. Usage in 1995 is estimated to be less than 22 percent of 1989, and manufacturers have committed to complete elimination of ODSs within the next few years.

Update on the Essential Use for Rocket Applications

National Space and Aeronautics Administration (NASA)/Thiokol was granted an essential use production exemption for 1996 and 1997. NASA/Thiokol have proceeded with their phaseout and are ahead of schedule for eliminating non-essential uses and investigating additional alternatives and substitutes. However, at this time NASA/Thiokol has not identified any acceptable substitutes that would reduce their essential use below the previously calculated amounts.

The Committee has confirmed that other U.S. and European solid rocket motors use these substances and that these organizations are expected to nominate additional essential uses by January 1, 1995 for decision in 1995.

The U.S. Titan program is working to completely eliminate the use of ODS and has invested substantial resources in successfully developing alternatives to ODS use. The prime contractor and the major manufacturers of Titan IV vehicle components will reduce all ODS use by 99 percent, from 1.33 million kg in 1989 to 9,200 kg in 1996. Four small-quantity ODS uses are critical to the success of the Titan SRMU.

Both CFC-113 and TCA are used in the Ariane Espace Program. Efforts to find substitutes for these programs concern CRYOSPACE for liquid rocket engines and Societe Européenne de Propulsion (S.E.P.) for solid motors.

The Japanese space rocket industry currently uses CFC-113 and TCA but expects to phase out the uses by the end of 1995.

Cleaning of Oxygen Systems

In January 1994 NATO identified the cleaning of oxygen systems as one of the most difficult challenges facing military and aerospace applications. Oxygen systems include: life support systems such as diving, totally encapsulated suits, emergency breathing devices, fire & rescue backpacks, submarine, aircraft, manned spacecraft, and medical applications; propulsion systems such as liquid oxygen rocket motors; industrial systems such as chemical production; and other unique systems and customer products such as welding equipment.

Case Studies

The Solvents TOC Report includes case studies of successful elimination of ozone-depleting solvents: Allied Signal, AT&T Bell Labs, Beck Electronics, Ford Motor Company, Hitachi, Honeywell, IBM Corporation, Japan Industrial Conference on Cleaning, Lockheed Sanders Company, Miljoministeriet, Minebea Company, National Semiconductor, Naval Aviation Depot Cherry Point, Northern Telecom, Robert Bosch Corporation, Rockwell International, Seiko Epson Corporation, Singapore Institute of Standards and Industrial Research, Swedish EPA, Toshiba Corporation, U.S. Air Force Aerospace Guidance and Metrology Center, and Vibro-Meter.

Total Equivalent Warming Impact (TEWI) of Solvent Uses

The Solvent TOC report includes a summary of the key findings of the AFEAS TEWI report. Solvent losses from cleaning equipment are potentially lower than assumed in the 1991 study resulting in lower calculated contributions to TEWI. The no-clean systems, used for the manufacture of printed wire assemblies, have the potential for the lowest TEWI. For metal cleaning, chlorocarbon-based systems (e.g., perchloroethylene , trichloroethylene) have the potentially lowest TEWI. The PFC system studied has the highest TEWI. Semi-aqueous and alcohol systems generally have been shown to have a lower TEWI than HCFC and HFC-based systems.

Sector Progress: Laboratory and Analytical Uses

Carbon tetrachloride, CFCs, 1,1,1-trichloroethane and other ozone-depleting substances are currently necessary for a number of important laboratory and analytical applications. These uses are allowed in 1996 and 1997 under terms of the Essential Use Exemption as granted by the Parties at their 1994 Meeting. The government of Canada hosted a workshop in November 1994 to begin to coordinate efforts to reduce such uses.

Sector Progress: Economic Issues

The transition from the ODS phaseout in developed countries to the early stages of the phaseout process in the developing countries has seen evidence of a re-thinking of priorities, mechanisms and resourcing of the Montreal Protocol process. The Economic Options Committee (EOC) Report develops the transition theme by pointing out the remarkable achievements recorded so far and calling attention to the scope for improvements through addressing the concerns of the developing countries. The record of achievement and the capacity for future progress is largely enabled by the network of experts (e.g. industrialists, scientists, technologists, policy-makers, economists, NGOs) with a common interest in ozone layer protection.

A number of policy issues remain to be resolved, such as matching the global phaseout schedules of ODSs not already scheduled for phaseout to the most recent scientific and environmental assessments of the risks those substances pose to the ozone layer; ensuring the adequacy of the Multilateral Fund to fulfil its mandate; appropriately regulating transitional chemicals; managing the stock of existing ODSs to minimize premature obsolescence of ODS-using equipment; and the design of ozone layer protection policies that will encourage innovation and productivity growth as well as meeting the environmental imperative to protect the ozone layer.

The major specific concerns of the Article 5(1) countries that were brought to the attention of the EOC are (1) whether the political and financial support for the institutions of the Montreal Protocol will be adequate for them to fulfil their mandates; (2) whether the cooperative approach to the transfer of technology to the Article 5(1) countries will be sustained; and (3) whether supplies of ODSs and ODS alternatives will be available at affordable prices. Success in responding to these concerns will depend largely on the capacities and resourcing of the network of experts working on ozone layer protection.

International Trade and the Basel Convention

The Basel Convention has the potential to be a serious impediment to the transshipment of recycled CFCs/halons or CFCs/halons to be recycled across international boundaries. Whilst the Montreal Protocol allows unrestricted trade in recycled CFCs/halons between signatories, as described below, the Basel Convention could be used to restrict trade. This is further complicated by the fact that not all signatories to the Montreal Protocol are signatories to the Basel Convention, and that technically, signatories cannot trade with non-signatories unless a bilateral agreement exists which is no less stringent than the Basel Convention requirements.

The Halons Technical Options Committee is working in cooperation with the Basel Technical Working Group to ensure that if recycled CFC or halon is uncontaminated, or has already been reprocessed to service specification, then it will not be considered a hazardous waste or waste at all, and hence exports of the material would be unaffected by the Basel Convention. For this reason, the Halons Technical Options Committee recommends that the Parties to the Montreal Protocol consider:

a) Adopting a decision that recycled CFCs/halons that are certified to the usable purity specifications (in the case of halons ISO 7201 or ASTM ES 24-93) are considered recycled materials and not a waste.

b) Adopting a decision that international transfers of CFCs/halons that cannot meet the purity specifications (in the case of halons ISO 7201 or ASTM ES 24-93) should only be allowed if the recipient country has recycling facilities that can process the received halon to either of these standards.

A separate decision of the Basel Convention will ban exports of hazardous wastes from the Organization for Economic Cooperation and Development (OECD) to non-OECD countries after 1997. Again, if the Parties to the Montreal Protocol accept recommendations a) and b) above, this will greatly assist non-OECD countries in meeting their needs with recycled CFCs/halons instead of with new production.

Reorganizing the TEAP and its TOCs for sustainable operation

As a result of the remarkable success of the Montreal Protocol, the TEAP and its TOCs need to continue to evolve and undergo revitalization in order to serve the needs of the Parties. As the phaseout is successfully completed in developed countries, there is less support from companies and organizations that have solved their own technical problems and many environment ministries are withdrawing staff and resources from ozone layer protection. Furthermore, the needs of the developing countries are increasing as their phaseout progresses.

The character of the work has shifted from evaluation of the substitutes and alternatives to the ODSs scheduled for 1994 and 1996 phaseout to the assessment of alternatives and substitutes to HCFCs and methyl bromide. The assessment of Essential Use Nominations may continue to be important. Additional work involves new and temporary issues which require the contribution of experts not typically found on the Panel and its TOCs. Examples of this recent specialization of work include investigations of Destruction Technologies, Inadvertent Production, Laboratory and Analytical Uses, and Process Agents.

In 1995 the Panel will refocus, simplify, and consolidate the Panel and Committees. It is possible that the Solvents, Coatings, and Adhesives Technical Options Committee will be merged with the Aerosol Products, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee and consideration is being given to merging the Economic Options Committee functions into the Panel itself. Committees will be adjusted with improvements in geo-political balance. Participation by organizations that market ozone-depleting substances but do not offer alternatives and substitutes will be reevaluated. Every Committee will be asked to reduce participation of developed country experts with a goal of forty or fewer participants per Committee, but with an increase in the number of developing country participants.

These changes will increase developing country participation, reduce Committee management and logistical expenses, and will improve technical efficiency.

1 Introduction

1. Introduction - Montreal Protocol Process

1.1 Ozone depletion and other environmental considerations

The concentration of ozone in the earth's atmosphere varies with altitude, latitude and seasons. The maximum concentrations are found in the stratosphere at altitudes of 25-40 kilometres. Ozone is created by the action of ultraviolet (UV) radiation from the sun on oxygen molecules (O_2) creating ozone (O_3). Ozone has the ability to reduce harmful UV-B radiation from the sun reaching the surface of the earth.

Chlorine and bromine containing compounds, that are stable, migrate to the stratosphere where over time the high energy radiation from the sun causes them to decompose, releasing the chlorine and bromine. The chlorine or bromine then reacts with the other gases in the stratosphere. The result is a reduction in the concentration of stratospheric ozone. Each chlorine or bromine atom can participate in 10,000-100,000 destruction reactions before being fixed as hydrochloric or hydrobromic acid, and washed out of the atmosphere. The Ozone Depletion Potential (ODP) provides a useful yardstick for estimating the relative destruction potential of various chemicals.

Chemicals which contain only chlorine, fluorine and carbon are called fully halogenated chlorofluorocarbons or simply CFCs. Similar compounds, which contain one or more hydrogen atoms, are not fully halogenated and are called hydrochlorofluorocarbons or HCFCs. The presence of the hydrogen atom reduces their stability in the atmosphere and hence their adverse impact on the ozone layer. Chemicals containing fluorine, carbon and hydrogen, but no chlorine or bromine, are referred to as hydrofluorocarbons (HFCs).

The halons, primarily used as fire extinguishing agents, consist of carbon, fluorine, bromine and possibly chlorine and deplete the ozone layer in a similar manner to the CFCs, only more severely (this is reflected by the ODP value, see Table 1.1). Other anthropogenic chemicals, such as 1,1,1-trichloroethane (methylchloroform, CH_3CCl_3), carbon tetrachloride (CCl_4), and methyl bromide also contribute to ozone depletion.

An additional property of the CFCs, halons, methyl bromide, and fluorinated compounds, including those that are under consideration as substitutes for CFCs, is their ability to absorb infra-red radiation at wavelengths that make them potential contributors to an enhanced greenhouse effect. Similar to the ODP, the global warming potential (GWP) is used to provide a measure of the relative contribution of an atmospheric gas to global warming and climate change. Three major factors determine the relative contribution of the gas to radiative forcing: the position and strength of the absorption bands of the gas, its lifetime in the atmosphere, and the time period over which the climate effects are of concern. Across the ODSs and their chemical substitutes there is a wide variation in GWPs. Greenhouse gases are already controlled by voluntary agreements under the Climate Convention, while legally binding controls are being negotiated.

Since the ozone depletion potential and the global warming potential are ways of comparing the adverse environmental impacts of chemicals, both need to be taken into account when assessing environmental acceptability. The use of any compound that accumulates in the atmosphere carries some potential risk with regard to atmospheric, human health and environmental effects. It is also important to consider other environmental, health, and safety considerations such as consumer and worker safety, toxicity, flammability, energy efficiency, air pollution, and others, when evaluating alternatives. A summary of estimated values for ozone depletion and global warming potentials is given in Appendix B.

1.2 Montreal Protocol

In 1981, in response to the growing scientific consensus that CFCs and halons would ultimately deplete the ozone layer, the United Nations Environment Program (UNEP) began negotiations to develop multilateral protection of the ozone layer. These negotiations resulted in the Vienna Convention for the Protection of the Ozone Layer, in March 1985. The convention provided a framework for international cooperation in research, environmental monitoring and information exchange.

In September 1987, 24 nations, including the United States, Japan, the Soviet Union, the European Community (EC) and country members of the EC, signed the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol entered into force on January 1, 1989. By April 1991, 68 nations had ratified the Protocol. These countries represented over 90 percent of the world's production of CFCs and halons. The 1987 Protocol limited production of CFCs to 50 percent of 1986 levels by the year 1998 and limited production of specified halons at 1986 levels starting in 1992. The Protocol also contains the requirement of technical and scientific assessments, to be undertaken at least every four years.

As of 30 September 1994 the Montreal Protocol has been ratified by 139 countries. The London Amendment has been ratified by 93 Parties and entered into force on 8 October 1992, and the Copenhagen Amendment has been ratified by 34 Parties and entered into force on 14 June 1994.

A list of CFCs, halons and other substances controlled under the Montreal Protocol is shown in Table 1.1.

Shortly after the 1987 Protocol was negotiated, new scientific evidence conclusively linked CFCs to depletion of the ozone layer and confirmed that depletion had already occurred. Consequently, many countries called for further actions to protect the ozone layer by expanding and strengthening the original control provisions of the Montreal Protocol.

In June 1990, the Parties to the Montreal Protocol met in London and agreed to Protocol adjustments requiring more stringent controls on the CFCs and halons that were specified in the original agreement and amendments placing controls on other ozone depleting substances, including carbon tetrachloride and 1,1,1-trichloroethane. The Parties were informed by three Panel reports, one on the science of ozone layer depletion, one on its effects, and a third one on technology and economics. The latter report, of the Technology and Economic Assessment Panel, was based upon six Technical Options Committees that undertook assessments of the technology available to reduce the dependence on ozone depleting substances.

In London, a new assessment was proposed, which was endorsed during the Meeting of the Parties in Nairobi, 1991 (Decision III/12).

In 1991 there was a complete assessment of CFC, halon, 1,1,1-Trichloroethane, Carbon tetrachloride, and HCFCs. In 1992 a supplemental Atmospheric Science, Technology, and Economic Assessment reported the consequence of ozone layer depletion from anthropogenic emissions from methyl bromide and the technical and economic feasibility of reducing methyl bromide users and emissions. Based upon this information, the Parties at Copenhagen controlled methyl bromide and HCFC and decided new phaseout schedules for the substances already controlled. A seventh Technical Options Committee was set up to deal with issues relating to methyl bromide. The consequence of the Copenhagen Amendment is shown in Table 1.2.

The 1992 Copenhagen Meeting of the Parties to the Montreal Protocol directed the Scientific, Environmental Effects, and Technology and Economics Assessment Panels to report on:

(a) the scientific findings and observations regarding stratospheric ozone depletion and related phenomena and issues (e.g. Ozone Depletion and Global Warming Potentials);

(b) the environmental and public health effects of stratospheric ozone depletion;

(c) the technical feasibility and earliest possible date in each of the major use sectors, of reducing emissions and phasing out production and consumption of controlled (ozone depleting) substances and the related anticipated economic concerns.

The 1994 Technical and Economic Assessment study has been carried out by the Panel and its seven Options Committees:

(1) Aerosols, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride Technical Options Committee

(2) Rigid and Flexible Foams Technical Options Committee

(3) Halons Technical Options Committee

(4) Refrigeration, AC, and Heat Pumps Technical Options Committee

(5) Solvents, Coatings, and Adhesives Technical Options Committee

(6) Methyl Bromide Technical Options Committee

(7) Economic Options Committee

The Panel's seven current Committees consist of more than 300 experts from 38 countries (for a list see Appendix A).

The 1994 Technical Options Committees consist of some members of the 1989 and 1991 Committees and additional new experts. Experts from industry, government, academic institutions and non-government organizations prepared comprehensive and technically specific "Options Reports." Producers, equipment manufacturers, trade associations, users, research institutions, standards making organizations and others provided comprehensive technical input. The reports will be distributed internationally by UNEP.

This Report is part of the work of the Technology and Economic Assessment Panel under Decision IV/13. This report, as well as the reports of the two Panels on Science and Environmental Effects, will be considered by the Parties for further decisions to be taken at their 7th Meeting in Vienna, 1995.

1.3 Decisions of the Parties to the Montreal Protocol relevant to TEAP

There are a number of Decisions of the Parties to the Montreal Protocol which direct the work of the Technology and Economic Assessment Panel and its Technical Options Committees. Those that are current relate to Decisions from the fourth, fifth, and sixth meetings of the Parties. These Decisions are:

IV/13	Assessment Panels
IV/23	Methyl bromide
IV/25	Essential uses
IV/30	HCFCs
V/8	Consideration of alternatives
V/18	Timetable for the submission and consideration of essential use nominations
V/19	Control Measures to be applicable to Parties operating under paragraph 1 of Article 5 of the Protocol with respect to the controlled substances in Group 1 of Annex C, Group II of Annex C, and Annex E
V/20	Extension of application of trade measures under Article 4 to controlled substances listed in Group 1 of Annex C and in Annex E
VI/10	Use of controlled substances as process agents
VI/11	Clarification of the "quarantine" and "pre-shipment" applications for control of methyl bromide
VI/13	Assessment Panels
VI/19	Trade in previously used ozone-depleting substances

Full texts of these Decisions are given in Appendix B.

In 1993 and 1994, the Technology and Economic Assessment Panel issued a progress report on the success in reducing the use and emissions of controlled substances. In 1994, the report, in response to Decision IV/13, contained information on essential use recommendations, on recovery and recycling, on inadvertent losses during production and handling, and also on HCFCs. The latter requirement was according to Decision IV/30 on "HCFCs." The Parties also decided a new assessment was to be carried out in 1994 according to Decision IV/13.

As a part of the continuing concern of the Parties over appropriate controls on HCFCs, Decision V/8 requested the TEAP in its report for 1994 to consider technical feasibility, technical availability, country-specific circumstances, and environmental, health and economic aspects when considering HCFCs and alternatives to HCFCs. Decision V/19 and V/20 requested the TEAP, in collaboration with the Science Panel and the Secretariat and Executive Committee, to consider control schedules for HCFCs in Article 5(1) countries and the feasibility and implications of extending trade measures to trade in HCFCs as a part of method of control of HCFCs.

At the 4th Meeting, the Parties took Decision IV/23 relating to methyl bromide, which provides the basis for setting up the seventh Technical Options Committee, called the Methyl Bromide Technical Options Committee. This TOC is to report to the Parties through the TEAP on methodologies to control emissions of methyl bromide and their feasibility, and availability of alternatives to methyl bromide. Additional information relating to the control of methyl bromide (the only substance in Annex E of the Protocol) was requested in Decision V/19, V/20, and VI/13. This, in particular, related to the feasibility and possible base years for the control of methyl bromide in Article 5(1) countries. Decision VI/11 clarified some important definitions relating to the control of methyl bromide and requested further information on the subject.

Decision VI/10 concerned the use of ODSs as process agents and their control. This was to clarify the status of materials which were used during chemical manufacturing but did not strictly fall within the definition of feedstock under the Protocol. Decision IV/25 and V/18 allow Parties to continue to use ODS as process agents in 1996 and requests an assessment of such applications.

Decision VI/19 clarifies exemptions in relation to trade in recycled material and requests further data on the impact of this trade.

Table 1-1
Substances Controlled by the Montreal Protocol
(ODP values are relative to CFC-11)

Annex A

Group I		ODP
CFC - 11	Trichlorofluoromethane	1.00
CFC - 12	Dichlorodifluoromethane	1.00
CFC - 113	1,1,2-Trichloro-1,2,2-trifluoroethane	0.80
CFC - 114	1,2-Dichlorotetrafluoroethane	1.00
CFC - 115	Chloropentafluoroethane	0.60

Group II		
Halon 1211	Bromochlorodifluoromethane	3.0
Halon 1301	Bromotrifluoromethane	10.0
Halon 2402	Dibromotetrafluoroethane	6.0

Annex B

Group I		
CFC - 13	Chlorotrifluoromethane	1.00
CFC - 111	Pentachlorofluoroethane	1.00
CFC - 112	Tetrachlordifluoroethane	1.00
CFC - 211	Heptachlorofluoropropane	1.00
CFC - 212	Hexachlorodifluoropropane	1.00
CFC - 213	Pentachlorotrifluoropropane	1.00
CFC - 214	Tetrachlorotetrafluoropropane	1.00
CFC - 215	Trichloropentafluoropropane	1.00
CFC - 216	Dichlorohexafluoropropane	1.00
CFC - 217	Chloroheptafluoropropane	1.00

Group II		
CCl_4	Carbon Tetrachloride (Tetrachloromethane)	1.10

Group III		
1,1,1-Trichloroethane	Methyl Chloroform (1,1,1-Trichloroethane)	0.10

Annex C

Under Annex C, the Montreal Protocol defines partially halogenated fluorocarbons, (including HCFCs)

Group I Hydrochlorofluorocarbons(HCFCs)

Group II
Hydrobromofluorocarbons

Annex E

MeBr	Methyl Bromide	0.6

Table 1-2
Control Measures Status 1994

Annex A - Group I
Chlorofluorocarbons: CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115
Reference year: 1986
75 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex A - Group II
Halons: halon 1211, halon 1301 and halon 2402
Reference year: 1986
100 percent reduction by January 1, 1994 (with possible exemptions for essential uses)

Annex B - Group I
Other fully halogenated CFCs
CFC-13, CFC-111, CFC-112, CFC-211, CFC-212, CFC-213, CFC-214, CFC-215, CFC-216, CFC-217
Reference year: 1986
Freeze at 1986 levels by July 1992
85 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex B - Group II
Carbon Tetrachloride
Reference year: 1989
85 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex B - Group III
1,1,1-trichloroethane
Reference year: 1989
50 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex C - Group I
HCFCs
Reference year: 1989
Freeze in 1996 based on 3.1% of 1989 CFC ODP Consumption PLUS Calculated level of 1989 HCFC Consumption
35 percent reduction by January 1, 2004
65 percent reduction by January 1, 2010
90 percent reduction by January 1, 2015
99.5 percent reduction by January 1, 2020
100 percent reduction by January 1, 2030

Annex C, Group II
HBFCs
100 percent reduction by 1996

Annex E
Methyl Bromide
Reference year: 1991
Freeze at 1991 levels by January 1, 1995, with exemptions for quarantine and pre-shipment applications

2 Recent global CFC and HCFC consumption (1986 to 1993) and estimates for near future usage (1994 to 2000)

2.1 Introduction

This chapter provides estimates on the global CFC and HCFC consumption over the period 1986-1993. These data have been largely assembled from chemical manufacturer sources to depict total CFC and HCFC use (mainly HCFC-22, and HCFC-142b) since 1986. The CFC use has been allocated between developed countries (separated with respect to CEITs), Article 5 countries and countries that are not Parties to the Montreal Protocol. This separation was made because the data available for the CEITs and Article 5(1) countries are not as detailed and for some years data are lacking.

Data has been obtained from several sources (confidential information from fluorocarbon manufacturers, implementing agencies and from Multilateral Fund Executive Committee reports); using this data, preliminary estimates are given for the use of CFCs and HCFCs in the developed countries (including CEITs) and in the Article 5(1) countries over the period 1994-2000.

The data assembled here provides insight into the remaining challenge to reduce and phase out global CFC use after 1993/1994. Amongst the different types of usages, the refrigeration and air conditioning sector has been and remains a dominant user of CFCs and other fluorocarbons worldwide. Specific data on the consumption by this sector are therefore presented.

This chapter presents estimated data that could not be critically analyzed by the TEAP and are therefore for information purposes only. The TEAP will report in its March 1995 report in a more elaborate form, after having developed own scenarios for future HCFC consumption.

Section 2.2 describes the data sources for CFC consumption, section 2.3 deals with the data collection and makes some observations regarding the use of CFC chemicals over the period 1986-1993, as well as for HCFCs over the same period. Section 2.4 deals with estimates for the future use of chemicals, in section 2.4.1 for CFCs in refrigeration, in section 2.4.2 for HCFCs and in section 2.4.3 for other chemical uses in refrigeration. Section 2.5 presents some concluding remarks.

2.2 Data sources for CFC use

It is difficult to obtain current accurate figures for CFC use or production. CFC data have been accumulated by an independent audit of production and sales from the twelve companies that comprise the AFEAS group (Alternative Fluorocarbon Environmental Acceptability Study). This effort builds on the original data gathering exercise started by the fluorochemicals producers under the U.S. Chemical and Manufacturers Association (CMA) Fluorochemical Program Panel (FPP). The CMA and AFEAS group also report an estimation of their share of the total world CFC production; this allows the estimation of global CFC production and sales (use).

The Japan Flon Gas Association (JFGA) provides market data and production figures for the combined Japanese fluorocarbon producers. Similar data are gathered by CEFIC, the

Western-European fluorocarbon industry trade group.

UNEP data are incomplete but significant information exists in the UNEP document UNEP/ OzL/ Pro 5/5, published in 1993 (Bangkok 17-19 November 1993), as well as in the same type of UNEP document (UNEP/ OzL. Pro 6/5, 15 July 1994) published in 1994. Data in these reports permit verification of the U.S., Japan and Western European information as well as a few benchmarks for other important producers and users of CFCs.

U.S. data have not been made public by the U.S. government or trade groups beyond what appears in the above mentioned UNEP document. Data from a large global fluorocarbon supplier of CFCs, which has a reasonably comprehensive data base, have been used to quantify the U.S. as well as other markets. A report by the U.S. Congressional Research Service (April) and several trade magazine articles were examined to verify or fill in data gaps. It would appear that the aforementioned data sources seem to be the source of all other published numbers; hence it is easy to fall into a circular verification trap.

UNEP/OzL.Pro/ExCom/8/25 (21 September 1992) presents estimates of the total ODS usage for Article 5(1) countries only. Data presented in this chapter are consistent with that in the 1992 UNEP publication.

UNEP/OzL.Pro/ExCom/14/5 (7 September 1994) is a preliminary document that gives an overview of the costs of various phaseout strategies in the developing countries. This document mentions a total use of 225,000 ODP tonnes in the Article 5(1) countries in 1993, derived using a specific analysis of data available (this figure includes halons, CTC and methylchloroform). Data in this chapter are in good agreement with the above document since it assumes a consumption of CFCs in the Article 5(1) countries in the order of 175,000 tonnes in the year 1993.

Information also exists from country programmes that have been approved by the Executive Committee of the Multilateral Fund. By mid 1994, 40 country programmes had been approved which are assumed to reflect a significant proportion of the use of CFCs in developing countries (accumulated data from these country programmes amount to roughly 130,000 ODP tonnes).

In summary, building on the information available from chemical companies for the use of CFCs in different parts in the world, together with other information, reasonably accurate data are provided for both the developed and the Article 5(1) countries' consumption over the period 1986-1993.

2.3 Data analysis

2.3.1 CFC Consumption 1986-1993

Table 2.1 (see also Fig. 2.1) presents a summary of the best available information for global consumption or sales of CFCs in the years 1986 through 1993, from CMA/AFEAS sources, as well as from separate manufacturer data. It builds upon data as given in Table 2.2 (AFEAS and CMA estimates). In Table 2.2, quantities of CFCs sold by AFEAS companies are given, as well as estimates by AFEAS for global consumption. Table 2.2 also gives the CMA reported data for the different application sectors over the period 1986-1992 (these data are only for CFC-11/-12 and totals are equal to the CFC-11/12 data reported to AFEAS, 1986/ 1992).

Table 2.1 gives consumption data for the developed countries (excluding CEITs), sales from the CIS, and consumption in Article 5(1) countries as reported to UNEP. Using the

AFEAS data for global consumption, data for the CEITs and Article 5(1) countries are derived. Assuming that consumption in CEITs is mainly from sales by the CIS, Article 5(1) country consumption data are derived.

Some important observations from Table 2.1 are:

1. Total CFC use in the developed countries (excluding CEITs) has declined by 65% over the period 1986-1993, from 862 kt in 1986 to 302 kt in 1993.

2. In the same time frame, it appears that CFC consumption in the CEITs and Article 5(1) countries has remained in the 250 to 270 kt/year range (reduction in the CEITs, growth in Article 5(1) countries).

3. CFC consumption in the Article 5(1) countries in 1993 is expected to be in the range of 160-180 kt (value of 170 kt for 1992, given in Table 2.1).

4. In 1994, it is expected that CFC consumption in developed countries (excluding CEITs) will be comparable to the use in the CEITs and Article 5(1) countries, (in 1993, the consumption was about 300 kt and about 270 kt in the developed countries and in the CEITs plus Article 5(1) countries, respectively). It can also be anticipated that the use of CFCs in the Article 5(1) countries will be comparable to the use of CFCs in the developed countries (excluding CEITs) by the end of 1994.

2.3.2 CFC Consumption in refrigeration 1986-1993

Table 2.3 gives data for the global refrigerant sales, derived by AFEAS from the total global consumption as given in Table 2.2 (using extrapolation from CMA/AFEAS data for the different application sectors over the period 1986-1993). Table 2.3 also gives an estimate from the industry on CFC consumption in refrigeration over the period 1986-1994. Differences between the two sets of data are thought to be found in the build-up of global inventories (not charged into equipment but available for future use somewhere in the distribution chain).

Some inventory build up can be inferred from the refrigeration sales peaks in the 1987 to 1989 time frame (30 to 70 kt). Based on various government actions and trade comments it is likely that an additional CFC inventory could be accumulated in 1994 and 1995, as production and consumption allowances may exceed near term demand. This latter CFC inventory could be 80 to 170 kt, or 35 to 65% of a year's demand for global consumption in all sectors (as the footnotes in Table 2.3 explain, significant changes in refrigeration market dynamics are shrinking the CFC and CFC alternatives markets). The combination of smaller refrigerant charges in new equipment, no venting regulations, high excise taxes (U.S. market primarily), higher CFC prices and a concerted effort to eliminate CFC waste has reduced the total global refrigerant market by about 25% from historical volumes and has also reversed the 2.9%/year global growth rate that existed in the decade preceding the 1987 Montreal Protocol.

The best estimate of future fluorocarbon (CFC) demand for refrigeration, (see Table 2.3) will be met by a combination of:

- smaller charges in new equipment,
- improvement in containment,

- recycle and recovery of CFCs from old equipment,

- recycle of CFCs equipment retrofitted to HFCs and or HCFCs,
- replacement of CFCs in the new equipment market (OEM), by the use of CFC alternatives, hydrocarbons and not-in-kind methods, and
- continued use of CFCs in the developing nations.

Global experience in curtailing CFC use has occurred under a wide range of government and private sector activities. The following observations apply to the use in the refrigeration market:

- in the U.S., the combination of no venting or other application prohibitions, a rapidly accelerating excise tax, several national solvent and refrigerant recycle programs and a rapidly growing retrofit market have not only reduced overall CFC use by about 65% but cut refrigerant use by 50% from 1986 to 1993.
- the European Union (E.U.), has relied heavily on volume reduction schedules to meet their year end 1994 total phaseout date. However, despite progress in other sectors, in the 1986 to 1993 time frame total refrigerant use has remained constant or even increased slightly (by 19% in the year 1993 compared to the 1986 reference year) in the E.U.
- Japan has used a strong industry/government partnership and annual reduction schedules to accomplish its total CFC reduction that includes about a 25% cut in refrigerant use between 1986 and 1992 (latest year for which data are officially available).

Table 2.4 (see also Fig. 2.2) summarises refrigerant use in the developed countries (excluding CEITs) and infers the use by the other countries (CEITs and Article 5(1) countries). Global refrigerant use over the 1986-1993 period is also given in Table 2.4. The data suggest that, while a 38% reduction in developed country (excluding CEITs) refrigerant use has occurred since 1986, there was still CFC refrigerant use in these developed countries of 130 kt in 1993.

The use of Tables 2.4 provides a good summary of the developed, the CEIT and the total world refrigerant markets. As of 1993, the global CFC refrigerant use was about 240-250 kt with 60-65% used in developed countries (including CEITs) but also 35-40% used in the Article 5(1) countries. Although the figure for the Article 5(1) countries results from a subtraction of consumption values for small developed countries and CEITs (where no very accurate data are available) from the global consumption, the estimates for 1989-1993 have a 6-7 kt/year uncertainty. The assumption used in Table 2.4, in order to derive Article 5(1) consumption, i.e. that the CEITs consume in the order of 18-22 kt/year, appears very reasonable (information from UNEP data reporting, preliminary country programmes).

In summary, the following observations can be made, for the period 1986-1993:

1. CFC refrigerant use in the developed countries has been reduced by 38%, with different figures for different developed countries (reduction in the U.S.A by 51%, in Japan by an estimated 30%, whilst there was an increase in the E.U. by 19%);
2. CFC refrigerant use in the Article 5(1) countries has increased by about 50% over the period 1989-1993;

3. Global CFC refrigerant use has remained more or less constant when comparing the years 1986 and 1993 (there has been a somewhat lower global refrigerant consumption over the period 1990-1992);

4. Values for CFC refrigerant use in the developed countries (excluding CEITs) are expected to be comparable to the values for refrigerant use in the CEITs and Article 5(1) countries by 1994.

2.3.3 CFC Consumption in other sectors 1986-1993

In other sectors CFC consumption has reduced substantially since 1986. In the U.S., Japan and the E.U., the percentage of CFCs used in sectors other than refrigeration amounted to 76% in 1986, and had decreased to 56% in the year 1993 (derived from Table 2.4), which implies that the other sectors had decreased from 584 kt to 151 kt over the period 1986-1993, a consumption reduction of more than 70%.

Sectors that have achieved the largest reductions are the aerosol products sector, the solvents and, to a lesser degree, the foam blowing agents sector; halons are not considered here.

From CMA data, a reduction in the use of CFC-11/-12 of 95% for aerosol products in developed countries of 95% can be observed, over the period 1986-1993. However, since these data do not involve all CFCs used as propellants, however, and since these data do not consider CEIT and Article 5(1) countries, the only conclusion can be that the global use of CFCs for aerosol products has decreased substantially (presumably by 70-80%). Comparable values will be made available in the relevant Technical Options Committee Report.

From CMA data, a reduction in the use of CFCs as blowing agent over the period 1986-1992 can be derived for the developed countries. This reduction is about 33% over this period; it is estimated that the reduction will be in the order of 50% over the 1986-1993 period (see for more detailed data the Foams Technical Options Committee report).

However, the large reductions hold specifically for a number of developed countries. If the total, global CFC consumption over the years 1986-1993 is taken for all developed countries (including CEITs) then the values are 982 kt and 473 kt for the years 1986 and 1992, a reduction by roughly 50% (see Table 2.1, global AFEAS estimate minus Article 5(1) country consumption). This smaller reduction is mainly due to phaseout problems in the CEITs, in all application sectors.

2.3.4 HCFC Consumption 1986-1993

There are few published sources of HCFC production. There are no UNEP data since the materials do not come under control until 1996. The most reliable and complete data source is the AFEAS publication, "Production, Sales, and Atmospheric Release of Fluorocarbons Through 1992". This document covers the CFCs and HCFC-22 (AFEAS has also published data on the production of HCFC-142b over the last ten year period). Data from 1993 and later will be reported for other CFC fluorocarbon alternatives when three or more producers report a combined production of ten thousand or more metric tonnes per compound in any year. The AFEAS report on 1993 data is not expected to be available until sometime in 1995.

In a first instance, AFEAS HCFC-22 data and a single global producer's estimate for HCFC-22 have been taken; these data have been separated to refrigerants and propellants/ blowing agents. It is believed that the AFEAS data cover more than 95% of the global HCFC-22 production for the world through 1992. The producer's data appear to represent about 80% of the total global amount (this could be judged from visual comparison of the data between 1987 and 1992).

Table 2.5 (see also Fig. 2.3) is a factoring of the AFEAS and producer's data to approximate the total global volumes; the AFEAS figures were increased by 5% and the producer's figures were increased by 20%. These "factored" figures suggest that the global HCFC-22 refrigerant use has been in the 200 kt range for the last five years (industry estimate for the period 1989-1993). Over the period 1987-1992, according to AFEAS data, the global use of HCFC-22 refrigerant has increased by 27% (and the global use of HCFC-22 for refrigeration, blowing agents and propellants has increased by 42%).

The HCFC-22 refrigerant demand in the world's largest "HCFC-22 segment", the U.S., has or will decline by about 25% from traditional levels due to smaller charges in new equipment and no venting regulations. It also is expected that this decline will lead to a rather flat HCFC-22 type refrigerant demand for the rest of this decade, since HFC blends and other non-ODSs will likely displace some HCFC-22 use.

2.4 Estimates for future use of refrigerants

Tables attached to this section will give estimates concerning the future consumption of CFCs and HCFCs, and their consumption for refrigeration by using:

- extrapolated data from fluorocarbon manufacturers,
- information from implementing agencies,
- information from UNEP on current and future consumption in Article 5(1) countries,
- data from the 1994 UNEP TOC Refrigeration report and earlier TOC reports,
- assumptions on the replacement of CFCs and HCFCs,
- assumptions on the use of non-fluorocarbons and other alternative methods,
- assumptions on the application of recycling to CFCs, HCFCs and HFCs.

Data could not be critically analyzed by the TEAP and are for information purposes only; the TEAP will report in a more elaborate form in its March 1995 report.

2.4.1 CFC use over the period 1993-2000

Table 2.9 (see also Fig. 2.5) gives an estimate of the total use of CFCs in the developed and the Article 5(1) countries for all uses. Data for this table were derived from data in earlier tables (AFEAS/CMA based estimates and other data), from manufacturer estimates for the future market, as well as from the assumed consumption of HCFCs (average of manufacturers estimates, see section 2.4.2) given in Table 2.9 as well. In the case of refrigeration and air conditioning, the use of recycled and stockpiled material is not considered.

Table 2.8 presents an estimate of CFC production from Article 5 paragraph 1 country production facilities and the 15% allowance potentially available from developed country plants. The potential supply could be 338 kt/year for all application sectors assuming the 15% allowances are all produced. There is concern in developing countries on whether producers will consolidate these production rights or whether they will halt CFC production. On the other hand, market demand for CFC refrigerant is expected to be around 200 kt globally in 1994-1995. These estimates suggest substantial excess supply. However, if the global demand for CFCs for aerosol products, foam blowing etc. remain significant in the Article 5(1) countries, the estimated excess supply could be much more modest.

2.4.1.1 CFC use in refrigeration and air conditioning

It is clear that the use of CFCs in refrigeration and air conditioning will rapidly decline in developed countries (including CEITs) over the period 1993-2000. However, phaseout problems in a number of countries will lead to a consumption of about 10-40 kt over the period 1996-1999. In the Article 5(1) countries, CFC consumption is estimated to slightly increase in the refrigeration and air conditioning sector over the years 1993-1997 (reduction and phaseout in certain applications, together with a market growth); both effects will lead to a global consumption of about 100 kt of CFCs for refrigeration in 2000, which will mainly be in the Article 5(1) countries.

Refrigeration, air conditioning and heat pumps are the only significant users of CFCs and HCFCs for servicing (other small servicing uses of CFCs include heat transfer and pneumatic fluids).

Recycling and recovery plays an important role in refrigeration and air conditioning. In the developed countries, servicing amounts are expected to be 155-170 kt in the year 1994. They will have decreased in the year 2000 to somewhere between 125 kt (if 5% of the CFC equipment is retrofitted or replaced per year) and 35 kt (if 25% of the CFC equipment is retrofitted or replaced per year).

The above estimates do not deal with the Article 5(1) CFC refrigerant use for refrigeration servicing; it is very likely to be 65-75 kt/yr as of 1994 with growth rather than reduction in consumption in the above time frame.

The extent to which this quantity can be supplied from recycled amounts in developed countries remains uncertain, but it can be assumed that it could be covered by amounts recovered (on-site and centrally) and stockpiled (80-170 kt), from 1996 onwards.

The volumes of CFCs available for recycling depend on the equipment inventory or "bank" of refrigerants in these systems. The "bank" can be used as internal recycle when equipment is serviced, and be made available for other uses when equipment is retrofitted or replaced. In other cases, contamination could make refrigerants unusable.

European experience suggests that 50% of CFC refrigerant sales are for servicing installed or existing equipment (the U.S. figure is 75% which may be influenced by the large fleet of automotive air conditioners). Europeans also suggest using an average equipment life of ten years. By using Table 2.4 for refrigerant consumption in the U.S.A., Japan, and the E.U., and adding an estimated quantity of 355 kt for the years 1985 and 1984, it would yield a refrigerant use for these three regions of 1624 kt over the last ten years (1984-1994).

Assuming that 50% was for service and 50% for new equipment, the bank would be 50% of the 1624 kt, or 812 kt. On an annual basis, it is possible that 1/10 or 81 kt is potentially available for recovery. Using the U.S. experience of 25% for new equipment would suggest about 400 kt rather than 812 kt would be inventoried in existing equipment. Therefore, the potential available for recovery could well be about 40 kt.

Another approach is to examine actual recovery experience. European Union data for 1993 indicates that about 1 kt or 3% of the 1991-1992 sales volume was recovered in central facilities. Applying this 3% figure to the 1993 sales in the U.S.A., Japan and the E.U. would suggest a recovery potential of about 9 kt per year (3% of 302 kt). This central facility recovery rate seems very low compared to the annual recovery potential of 40-80 kt mentioned above, but it must be recognised that internal recycle or storage at the users' sites is likely to be quite significant. U.S. experience is similar to the E.U. in terms of refrigerant tendered to recovery stations for purification and resale. Based on this very limited experience of recovery plus the fact that the U.S.A. and Japan markets for CFC refrigerants have declined significantly, it can be assumed that internal recycling is possibly an order of magnitude larger than the amount returned to the open market for general use.

2.4.2 HCFC use over the period 1993-2000

Efforts have been undertaken to estimate the HCFC consumption for 1994-2000. Several manufacturers submitted (on a confidential basis) their best estimates for the sales of HCFCs over the next four to six years, split up over the different application areas. Data on the future sales of HFCs were also submitted (on a confidential basis). Both data have been used to derive a best guess scenario for the future global consumption of HCFCs in the developed (including the CEITs) and in Article 5(1) countries; these are also given in Table 2.9 (see also Fig. 2.4).

Table 2.7 contains a forecast of the HCFC-22 market and other HCFC refrigerant markets. In this table, the global consumption is given, as well as an estimate for the Article 5(1) countries. Global consumption for HCFC-22 refrigerants is expected to decrease over the 1996-2000 period. Other HCFCs for refrigeration (HCFC-123, -124 and possibly others) are expected to see a relatively small growth during the rest of the decade, both in the developed and Article 5(1) countries. Use of these HCFC refrigerants in the developed countries is expected to decline after the end of the 1990 decade.

The March 1995 TEAP report will provide further updated and elaborated estimates on HCFC refrigerant consumption and HCFC consumption in other application sectors.

2.4.3 Other chemical uses during the period 1993-2000

HFC and HFC based blends will take a certain portion of the refrigeration market, in this way reducing the dependence on HCFCs over the period 1994-2000. In 1989, chemical manufacturers forecasted that HFCs would take 8% of the reference 1986 CFC market; this percentage has increased over the last 5 years to about 25%, where it is also assumed that non-fluorocarbon and not-in-kind solutions, together with conservation measures, will take 50% of the reference 1986 CFC market.

HFCs, HFC based blends, ammonia and hydrocarbons are expected to play an important role in reducing the dependence on HCFCs (and CFCs, without the intermediate HCFC step), mainly in refrigeration. No data exist on the use of hydrocarbons in sectors that relied on CFCs in 1986. A significant volume can be assumed in the aerosol propellant and certain foam blowing applications in the second half of the 1990 decade. Although relatively minor, compared to the above uses, hydrocarbons are expected to be used in volumes of 2-5 kt in the refrigeration sector (mainly domestic appliances in the near future, according to estimates from the TOC Report Refrigeration). Volume data on the use of ammonia in refrigeration could so far not be determined.

2.5 Concluding remarks.

Table 2.9 (see also Figs. 2.4 and 2.5) presents estimated future consumption values, separated to the use of CFCs and HCFCs, and summarised over the different application sectors, both globally, and for the developed (including CEITs) and Article 5(1) countries. Values have been derived from different estimates (manufacturers, UNEP/ExCom reports), where also Tables 2.6 and 2.7 were used, which give the estimates for the refrigeration sector.

It can be observed that the total global consumption of CFCs is estimated to decrease steadily over the period 1993-2000, however, consumption could still be significant in the year 2000.

Therefore the world still envisages a substantial challenge to reduce the CFC consumption in both the developed and the Article 5(1) countries:

1. In refrigeration and air conditioning, the use in developed countries (including CEITs) is estimated to gradually decrease over the period 1994-2000; the use of new CFC material is estimated to be in the 0-10 kt range by the end of the decade (mainly due to phaseout problems in certain countries in the period 1996-1999).

2. For all other sectors, it is expected that CFCs will have been phased out by the end of the 1990 decade, in the developed countries (possibly including CEITs).

3. CFC consumption in developed countries has decreased substantially over the years 1990-1994, but there are considerable differences per region, especially in refrigeration, where e.g. the E.U. has increased its consumption. Large amounts are believed to be stockpiled, and considerable efforts are still required to manage the CFC phaseout.

4. Total world CFC consumption is estimated to be in the order of 100-120 kt by the year 2000 (mainly in Article 5(1) countries).

Concerning the use of HCFCs:

1. In 1989, the estimated total world HCFC consumption was about 250 kt, mainly consisting of HCFC-22 (and HCFC-142b) for refrigeration and air conditioning. This level has increased to about 300 kt/year by the year 1993, due to consumption in other application sectors as well.

2. Based on preliminary chemical manufacturer's estimates, the total world consumption of HCFCs is estimated to grow to a level of about 350-420 kt/year by the years 1995-1997, after which it will decrease. Developed country use of HCFCs will increase from about 250 kt (1989 value) to about 340 kt in 1996 which represents continued use of HCFC-22 and -142b and the use of other HCFCs to replace CFCs in the short term (HCFC-123, -124, and -141b).

3. The UNEP Technology and Economic Assessment Panel will elaborate on the technical and economical feasibility of reducing the HCFC cap and/or shortening the tail, established in the Montreal Protocol, as amended in Copenhagen. The TEAP report will give thorough estimates for future HCFC consumption in the separate application sectors. The TEAP will investigate several use scenarios to estimate future HCFC quantities in necessary applications.

Table 2.1

Total CFCS consumed or sold in different countries or regions, and global use (kt), compare Table 2.2; (sources: AFEAS/CMA, UNEP, preliminary country programmes, some 1993 data not available)

	1986	1987	1988	1989	1990	1991	1992	1993
U.S.A. Gov Dat + Industry Est	327	350	344	323	206	182	153	105
Japan - Flon Gas Data	133	156	159	161	111	96	61	46
Eur Union CEFIC Data	310	325	307	232	184	163	137	118
Other Developed UNEP Data[b]	92	—	—	68	58	38	35[a]	33[a]
Developed world (non CEITS) total	862	—	—	784	559	479	386[a]	302[a]
CIS - UNEP Data	120	—	—	110	110	—	87 (est.)	—
China - UNEP	19	—	—	26	35.5	43	—	—
Other Art 5 - as far as reported to UNEP	53	—	—	48	46	34	14	—
Non-Parties	10	—	—	—	2	7	3	—
Global sales AFEAS producers (see Table 2.2)	976	1063	1074	962	659	605	526	—
AFEAS + estimate for non-reported production	1133	1233	1245	1137	802	736	643	—
Unidentified to make total balance	69	—	—	169	49	173	240	—
Use by Article 5(1) countries	151	—	—	243	133	—	170	—

a - U.S./Japan/E.U. reduced 1993 use to 36% of 1986 base; assumed other developed countries did the same - 1993 value estimated at 33 kt. Estimated 1992 for other developed countries at 35 kt.

b - UNEP data is taken from UNEP/OzL Pro 5/5, August '93, Bangkok 17-19 Nov. '93.

Tables 2.2

Table 2.2(a)

CMA reported sales and AFEAS reported and estimated global production for sale (kt)

AFEAS Companies[a]

	1986	1987	1988	1989	1990	1991	1992	1993
CFC-11	350	382	376	302	233	213	186	—
CFC-12	398	425	421	380	231	225	216	—
CFC-113	197	226	247	251	175	148	108	—
CFC-114	19	17	16.5	15	8.5	6.5	5	---
CFC-115	12	13	13.5	14	11.5	12.5	11	—
Total	976	1063	1074	962	659	605	526	—

Table 2.2(b)

AFEAS Est. for World[b]

	1986	1987	1988	1989	1990	1991	1992	1993
CFC-11	412	449	442	356	274	251	219	—
CFC-12	469	500	495 .	469	312	300	288	—
CFC-113	218	251	275	279	194	164	119	—
CFC-114	21	19	18	17	9	7.5	5	—
CFC-115	13	14	15	16	13	13.5	12	—
Total	1133	1233	1245	1137	802	736	643	—

Table 2.2(c)

CMA reported data for CFC 11/12 sales
(Grant Thornton Report 1993

	1986	1987	1988	1989	1990	1991	1992	1993
Refrigeration and AC	224	247	—	272	—	195	195	—
Blowing Agents	253	291	—	277	—	195	170	—
Aerosol Products	224	225	—	96	---	31	23	—
Others	47	44	—	48	—	17	15	—
Totals	748	807	797	682	464	438	403	—

Footnotes to Tables 2.2

a - AFEAS Companies report actual production and sales by product type (CFC 11-12, etc.) and by industry segment to an Auditor that assembles and publishes the results.

b - AFEAS experts on atmospheric CFC measurements examine all available data and make estimates on the reporting fraction of global productions included in the AFEAS report. Dividing by these factors provides a reasonable estimate of total world productions and sales.

Table 2.3

Global refrigerant sales (CFCs only) 1986 - 1992 in thousand tonnes (kt)

Year	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Global[a]	253	277	302	312	215	231	230	—	—	—	—	—	—	—	—
Ind Est[b]	—	265	270	295	210	220	215	225	200						
Prod for Inven-tory	30 kt to 70 kt							50 kt to 100 kt							
Best estimate	250	250	240	230	210	230	230	230	200	160	140	130	120	110	100

Footnotes to Table 2.3

a - Global AFEAS (Line 1) are sales figures factored to cover rest of world; see line 10, Table 3.

b - Industry global estimate based on global producers' sales estimates.

Table 2.4

Trends in CFC refrigerant use only for different parts of the world (kt)

	1986	1987	1988	1989	1990	1991	1992	1993
U.S.[a]	132	132	128	145	80	81	76	65
Japan[a]	24.3	26.1	23.7	28.5	21.7	18.3	17.7	17[a]
E.U.	29.9	30.2	31	32.6	30.2	31.2	31.5	35.6
Sub-total US/Japan/EU[b]	186	188	183	206	132	131	125	118
Total CFCs[c] U.S./Japan/E.U.	770	831	810	716	501	441	351	269
% of Total[d] CFCs used in refrigeration U.S./Japan/E.U.	24%	23%	23%	29%	26%	30%	36%	44%
Estimate of other[e] developed (non CEIT) country refrigerant use	22	—	—	17	15	11	11	11
Estimate of total[f] developed (non CEIT) country refrigerant use	208	—	—	223	147	142	136	130
"Rough" estimate of refrigerant use for Article 5(1) and CEIT countries	45	—	—	89	68	89	101	117 (prelim est)
Rough estimate of refrigerant use in Article 5 countries				64 - 70	43 - 49	65 - 71	77 - 83	93 - 99
Total CFC refrigerant use	253	—	—	312	215	231	237	247

Footnotes to Table 2.4

a - Refrigerant data from Japan, U.S. and E.U. based on government, UNEP and trade group reports; (good agreement). Estimated U.S. 1986 figure based on 1987 & 1988. Estimated 1993 figure for Japan.

b - Sum of lines (1), (2) & (3); Japan, U.S., and E.U. CFC refrigerants only.

c - See total CFCs from Table 2.1.

d - Line (1), (2) & (3) divided by line (5).

e - Line (4) Table 2.1 x line (6) fraction of other developed countries total CFC use (25 - 30%).

f - Sum of line (1), (2), (3) and (7).

Table 2.5

Estimated HCFC-22 total world demand for dispersive or non-feedstock applications (kt)

	1987	1988	1989	1990	1991	1992	1993
Refrigerants[a]	171	196	204	189	212	218	—
Other Uses[a]	11	17	26	35	37	41	—
Totals[a]	182	213	230	224	249	259	—
Refrigerants[b]	—	—	206	194	206	216	220

Footnotes to Table 2.5

a AFEAS data as reported, multiplied by 1.05 to approximate total global production. This accounts for material produced primarily in the C.I.S. states and China.

b The single global producer figures available have been multiplied by 1.2 to approximate total global HCFC-22 for refrigerants.

Table 2.6

Use of CFCs in refrigeration in developed countries and Article 5(1) countries, consumption estimates for the period 1993 to 2000 (kt), (excludes the use of recycled CFCs for service, e.g. assumed in section 2.4, this table does not contain estimates of CFC quantities applied for essential use).

	1993	1994	1995	1996	1997	1998	1999	2000
Developed countries	120-140	80-100	30-40	25-40	20-40	10-20	5-10	5-10
Article 5(1) countries	95-100	100-105	105-110	105-110	100-105	100-105	95-105	90-100
Global	215-240	180-205	135-150	130-150	120-145	110-125	100-115	95-110

Table 2.7(a)

Use of HCFC-22 for refrigeration, global, developed and Article 5(1) consumption, estimates for the period 1993 to 2000 (kt)

	1993	1994	1995	1996	1997	1998	1999	2000
Developed countries	210-220	200-215	180-195	180-195	165-180	150-165	140-160	130-140
Article 5(1) countries	10-20	15-20	20-25	20-30	25-30	30-35	30-35	25-35
Global	220-240	215-235	200-220	200-220	190-210	180-200	170-195	155-175

Table 2.7(a)

Use of other HCFCs (123, 124 and 141b) for refrigeration, global, developed and Article 5(1) consumption, estimates for the period 1993 to 2000 (kt)

	1993	1994	1995	1996	1997	1998	1999	2000
Developed countries	2-5	7-10	9-13	15-19	17-19	18-20	20-22	20-22
Article 5(1) countries	<2	<2	<2	<2	2-6	2-6	2-6	4-8
Global	3-6	8-11	10-14	16-20	19-25	20-26	22-28	24-30

Table 2.8

Potential CFC production after 1995, for Article 5(1) countries domestic needs (kt)

	1986 Production[a]	Estimated Capacity[1]	15% Allowance[2,b]
E.U.	429	not available	64
Japan	132	not available	20
U.S.A.	354	not available	53
Eastern Europe	unknown	10	
C.I.S.	120[d]	unknown	18[d]
South Africa		10	
Republic of Korea		20[c]	
Subtotal for columns (1/2)			155
Potential supply (total of col's 1 & 2)			338[e,b]

Footnotes to Table 2.8

a Base figure used to calculate 15% post 1995 allowance for sales to Article 5(1) countries basic domestic needs, 15% not ODP adjusted

b Some of the 15% allowance may not be available past year end 1995, these figures could be 20-50 kt lower

c Republic of Korea considered Article 5(1)

d Will C.I.S. be held to 15% of 1986 base? Will their status change? Will the C.I.S. produce their 120 kt capacity?

e If the former Soviet States production (C.I.S.) is available beyond year end 1995, it could raise the potential total by about 100 kt above the 338 kt figure.

(1) & (2) are the estimated capacity and 15% allowance for Article 5(1) and developed countries

Table 2.9(a)

Use of CFCs, in developed countries and global, estimates for the period 1993 to 2000 (kt), derived from estimates (as well as from Tables 2.6 and 2.7)

	1993	1994	1995	1996	1997	1998	1999	2000
Developed countries	360-420	260-330	145-195	90-130	55-95	25-55	5-15	5-10
Article 5(1) countries	180-205	160-185	155-175	140-165	115-145	110-135	100-125	95-110
Global	540-635	420-515	300-370	230-295	170-240	135-190	105-140	100-120

Table 2.9(b)

Use of HCFCs, in developed countries and global, estimates for the period 1993 to 2000 (kt), derived from estimates (as well as from Tables 2.6 and 2.7)

	1993	1994	1995	1996	1997	1998	1999	2000
Developed countries	300-325	315-345	315-345	325-350	300-330	285-315	270-305	240-270
Article 5(1) countries	15-35	25-40	35-50	35-60	45-65	45-65	45-65	40-60
Global	315-360	340-385	350-395	360-410	345-395	330-380	315-370	280-330

Figure 2.1

Global consumption of CFCs 1986 to 1992
(see Table 2.1)

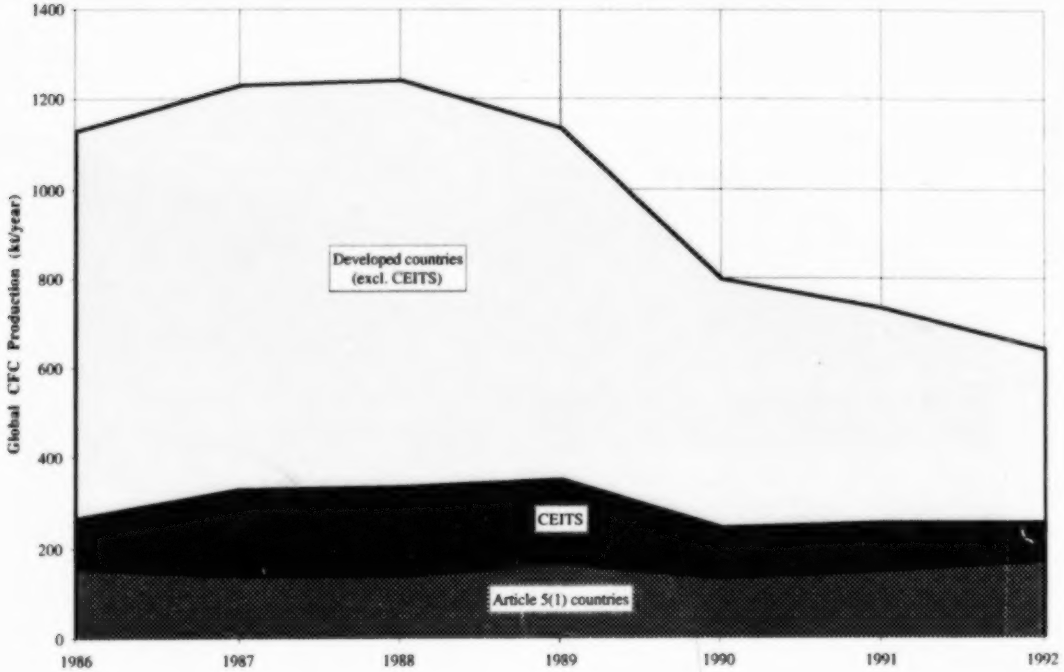


Figure 2.2

Global Consumption of CFC refrigerants 1986 to 1993
(see Table 2.4)

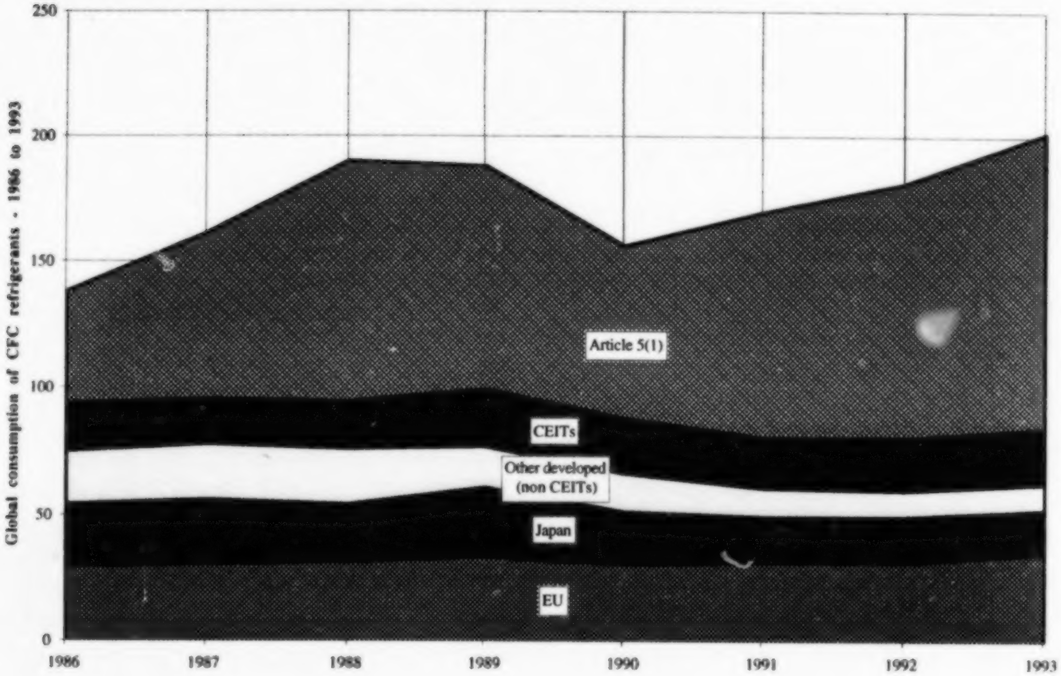


Figure 2.3

Global Consumption of HCFC-22 - 1987 to 1992
(see Table 2.5)

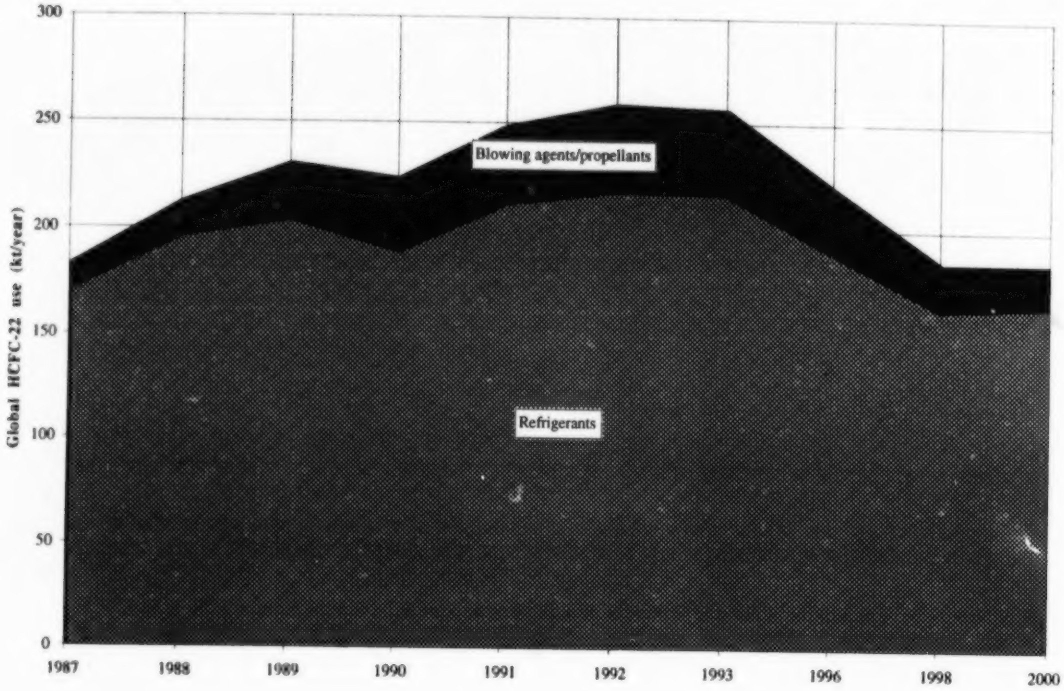


Figure 2.4

Estimates for future HCFC consumption - 1993 to 2000

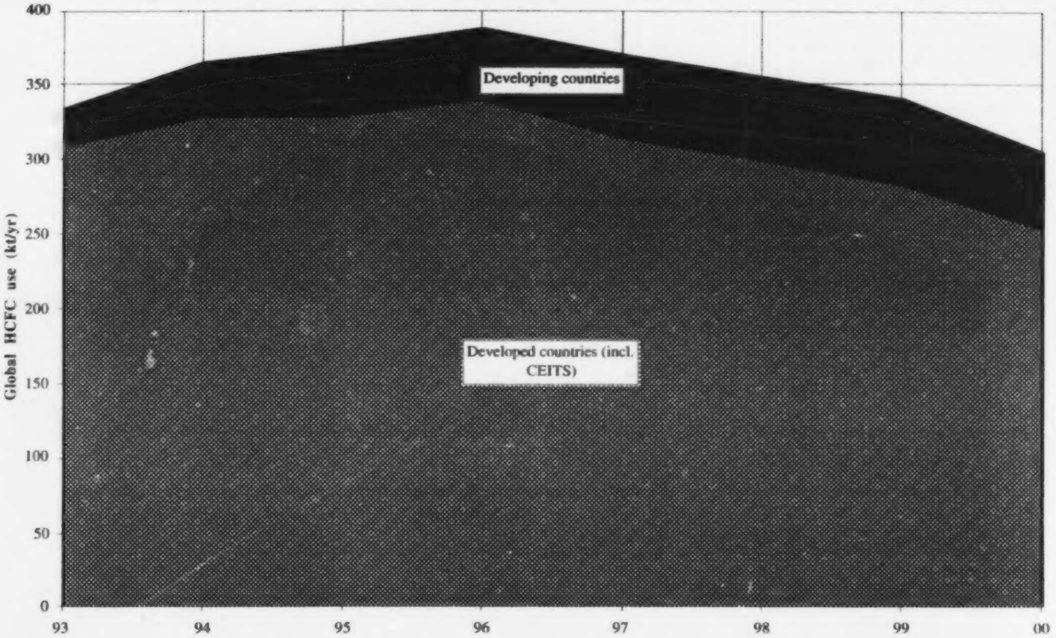
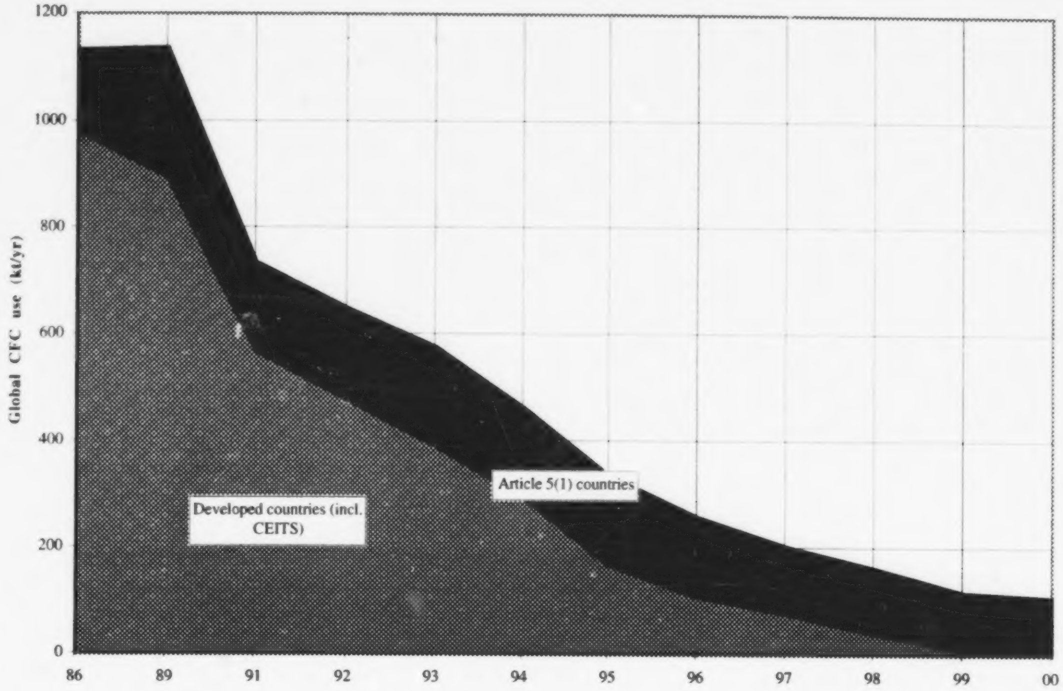


Figure 2.5

Estimates for future CFC consumption - 1993 to 2000
(see Table 2.5)



3 The technical feasibility of the phaseout schedule for Hydrochlorofluorocarbons (HCFCs) and Methyl Bromide in Article 5 Countries

This Chapter addresses requirements of Decision V/19. Further information will be presented by the Technology and Economic Assessment Panel (TEAP) in the March 1995 report because Decision V/19 has been superseded by Decision VI/13.

3.1 HCFCs

When the London Adjustments and Amendments were negotiated in 1990 it was believed that HCFCs would play an essential interim role in the chlorofluorocarbon (CFC) and halon phaseouts. It was estimated that many HCFC technologies would be investigated and commercialized as "transition chemicals" for the phaseout but later themselves replaced as other non-ozone-depleting technologies proved more cost effective. Accordingly, in London, only reporting was prescribed without controls for HCFCs. In Copenhagen, they were given a long phaseout schedule in developed countries. Due to uncertainty regarding their ultimate use, any decisions on a control schedule for Article 5 Parties was postponed until 1995.

HCFCs are currently extensively used worldwide for air conditioning, retail refrigeration, rigid thermal insulating and automotive safety foam, and in certain circumstances, as a drop-in substitute for existing sterilization equipment in hospitals and other small-scale uses. Since 1990 developed country use of HCFCs has not been as extensive as was initially thought necessary. Because of the early development of superior alternatives and substitutes, HCFCs are not generally used as substitutes in non-insulating foams, solvents, fire protection, domestic refrigeration, and many cold storage facilities. Just as with CFCs and halons, industrial innovation occurred far more rapidly than anticipated and the magnitude of HCFC use has fallen well below earlier expectations.

Part of the reasoning for the original 10-year grace period for developing countries was to allow them to take advantage of new technologies, tried and perfected in developed countries and to take advantage of lower prices achieved through subsequent economies of scale. When the decision on the grace period was taken, only a reduction of ozone-depleting substance (ODS) consumption was scheduled. Experts took the view that non-CFC technologies would be adopted more slowly in the developing countries. This strategy assumed that investors in the developed countries would take the larger part of the risks and costs of sequential technical choices regarding ODS alternatives. CFC users in developed countries were expected to shift to HCFCs in the near term, recognizing that they were transitional substances, and subsequently to bear the cost of eliminating HCFCs. Developing countries could take advantage of the experience in developed countries and select technologies that were most cost effective and suitable to their special circumstances.

Fortunately, there has been much more rapid progress than predicted in commercializing non-HCFC replacements for CFCs and halons. This has reduced the added expense of the phaseout by allowing many CFC users to move directly to ozone-safe solutions without a transition use of HCFCs and has thus dramatically reduced the originally anticipated demand for HCFCs. This technical and commercial experience, the availability of superior non-ODS alternatives and substitutes, and the cost of a two step move to non-ODS, also calls to question whether there is any advantage of a grace period.

Some of the disadvantages of an HCFC grace period are presented below, pending the further consideration of this issue in the March 1995 TEAP Report:

> A grace period could lead to investments in HCFC technology that could become obsolete if chemical producers choose to concentrate on markets for new chemicals.
>
> The costs of the Multilateral Fund could increase if two transitions are financed.
>
> Owners of HCFC equipment will face increasing difficulty in finding parts for equipment that is only marketed in a few locations.
>
> Developing country manufacturers will lose access to export markets because HCFC equipment import restrictions or because HCFC prices become prohibitive as the phaseout approaches.
>
> Obsolete HCFC equipment may be dumped in developing countries, increasing the difficulty of the ultimate phaseout.

The implications of this rapid technical progress are that developing countries can already replace CFC in many applications without resorting to HCFCs. Of course, there are sometimes significant constraints including lack of infrastructure, regulation, application engineers and scientists, and local data.

The Technology and Economic Assessment Panel and its Technical Options Committees expect that the technical feasibility of replacing ODS applications with non-HCFC alternatives will progressively reduce the demand for HCFC use in developing countries. In addition, HCFCs should only be replacements for CFCs where other, more economic and environmentally acceptable choices are not available. The evaluation of the technical and economic feasibility of HCFC controls in developing countries will be further discussed in the March 1995 report.

The TEAP has concluded that it is technically and economically feasible to reduce the HCFC cap in the developed countries due to the rapid development of alternatives and substitutes to HCFCs. Furthermore, if the Essential Use Process were applied to HCFCs, it could facilitate an early HCFC phaseout for new applications by providing the possibility that critical HCFC uses could be authorized by the Parties. The expanded 1995 evaluation will elaborate the technical and economic feasibility of reducing the HCFC cap and/or shortening the tail. If possible, the TEAP will investigate several scenarios such as "business-as-usual" with aggressive marketing and exaggerated new uses versus a "maximum feasible protection strategy" with balanced incentives for rapid CFC elimination and controlled HCFC dependence for new equipment.

The TEAP will also describe the history of technical development in applications where HCFCs were the first feasible alternatives to CFCs but are now no longer required. In some cases investigation of HCFC substitutes to CFCs was a necessary stepping stone that later enabled introduction of non-ODS alternatives. This discussion will also explore the consequences of requiring new investment by industry leaders who took early actions to protect the ozone layer by switching to HCFCs from CFCs when no other alternatives were available.

3.2 Methyl Bromide

A number of developing countries use methyl bromide as an aid to the production of certain high value cash crops for export to developed countries (e.g. cut flowers, strawberries, tobacco and some vegetables). Additionally, some developing countries use methyl bromide for disinfestation of cereal grain stocks.

In general, the alternatives to methyl bromide are, technically, the same in developed and developing countries. Therefore, with adequate financing of infrastructure for extension, local adaption trials, and incremental costs, developing countries could be subject to phase-out schedules and other restrictions similar to those for developed countries. Some temporary disruption to trade may be expected in any changeover to alternatives unless there is adequate time to plan. An exemption for pre-shipment and quarantine uses is appropriate until alternatives are developed and accepted by regulatory authorities.

In Decision V/19 the Parties asked the Technology and Economic Assessment Panel (TEAP) and its Methyl Bromide Technical Options Committee (MBTOC) to recommend a technically and economically feasible base year and grace period for possible control of methyl bromide in Article 5 countries. Among the concerns considered by the MBTOC and the TEAP are:

- To ensure consistency with economic structural adjustment programs and other economic development issues.
- To address the need to sustain food security.
- To permit time for the transfer and effective implementation of appropriate alternative technologies.
- To consider the potential for increased use of methyl bromide for export products due to methyl bromide restrictions in importing countries.

One option is to select a future base year and a grace period for developing country controls. Based on the above concerns, the MBTOC recommends that the Parties consider an average of consumption for the years of 1997, 1998 and 1999 as the base year and a nine (9) year grace period with technical option reviews conducted every three years to assess progress towards development and implementation of alternatives. Adjustment of the grace period could be made, if merited.

A disadvantage of a future base year is that chemical producers may aggressively market methyl bromide and new methyl bromide production facilities may be built in developing countries. This could result in unnecessary methyl bromide use and emissions, higher risk of poisoning farm workers in developing countries, and increased dependence on methyl bromide. It may further jeopardize access to export markets if markets in developed countries are resistant to products made with substances that deplete the ozone layer.

The TEAP recommends that Parties also consider other approaches to limiting unnecessary use of methyl bromide by developing countries.

Choice of a 1991 base year for developing countries would be consistent with that for developed countries and would eliminate the incentive to increase production in order to maximize consumption allowances in the future.

A second alternative is to exempt pre-shipment and quarantine uses but to cap the quantity of other uses in developing countries. For example, establish a 1998 freeze at base-year use with exemptions for pre-shipment and quarantine. Selection of a base year prior to 1995 would prevent sudden increases in production and use in order to increase the future allocation.

Another alternative is to prohibit the construction of new facilities so that global methyl bromide use cannot exceed existing levels as the developed Parties phase down or phase out. This option would avoid over-investment in methyl bromide production facilities that will soon be obsolete as alternatives and substitutes are commercialized and implemented.

Recommendation concerning Decision V/20

In Decision V/20 the Parties asked for recommendations on possible trade measures. The Methyl Bromide Technical Options Committee (MBTOC) and the TEAP recommends that the Parties consider:

1) As of January 1, 1996, each Party shall ban the import of methyl bromide from non-Parties (at this time, methyl bromide is only produced in countries Party to the Protocol).

2) As of January 1, 1998, each Party shall ban the export of methyl bromide to non-Parties.

3) By January 1, 1997, the Parties shall determine the feasibility of banning or restricting the import of products containing methyl bromide from non-Parties. If determined feasible, the Parties shall, following the procedures in Article 10 of the Vienna Convention, elaborate in an annex a list of such products. Parties that have not objected to the annex, in accordance with those procedures, shall ban, beginning one year of the annex having become effective, the import of these products from non-Parties.

4) By January 1, 1998, the Parties shall determine the feasibility of banning or restricting the imports of products made-with, but not containing methyl bromide from non-Parties. At the present time, the TEAP is not able to recommend any restrictions on products made-with but not containing methyl bromide, because of technical difficulties in detecting whether or not methyl bromide was used in their production or storage. If determined feasible, the Parties shall, following the procedures in Article 10 of the Vienna Convention, elaborate in an annex a list of such products. Parties that have not objected to the annex, in accordance with those procedures, shall ban, beginning one year of the annex having become effective, the import of these products from non-Parties.

Justification:

In fixing the time periods, the Methyl Bromide Technical Options Committee took into account the time needed by many countries for completing their ratification processes of the Copenhagen Amendment.

4 Feasibility of application of trade measures under article 4 to Hydrochlorofluorocarbons (HCFCs) and Methyl Bromide

The Panel and its Technical Options Committees considered the technical and economic aspects of possible trade measures for HCFCs and methyl bromide and for products made-with or containing HCFCs and methyl bromide, as requested under Decision V/20. Controls on HCFCs and methyl bromide have only recently been applied under the Protocol and it is thus difficult to estimate the full implications of possible trade measures. This essay should be considered preliminary and can be periodically updated if the Parties so desire.

4.1. Technical and administrative feasibility of possible trade measures to HCFCs

4.1.1 HCFCs

Because HCFCs are transitional controlled substitutes for chlorofluorocarbons (CFCs) in many applications, restrictions of trade of HCFCs could prolong dependence on CFCs and therefore result in greater harm to the ozone layer. Such uses include room air conditioning, a large part of commercial refrigeration applications, and most insulation foam applications and automobile safety foam. Education, technical assistance and financing could directly discourage the use of HCFCs in those cases where HCFCs are not necessary to eliminate CFCs. Such cases include typical solvent uses, virtually all aerosol uses, packaging, cushioning, and certain rigid insulating foam applications.

The Parties could save money by avoiding unnecessary dependence on HCFCs when financing the CFC phaseout because HCFCs will also have to be phased out.

The Parties may wish to reconsider trade measures in subsequent meetings when more Parties have ratified the Copenhagen Amendment, the phaseout is further along in developed countries, and preferred alternatives are more certain.

4.1.2 Products Containing HCFCs

It is technically feasible and administratively possible to identify products that potentially contain HCFCs. A list of such products which currently contain HCFCs would include: commercial refrigeration, cold storage, unitary and central air conditioning equipment (refrigerated cabinets, air conditioners, heat pumps); fire extinguishing equipment (fixed and portable fire extinguishers); insulating foam (including refrigerators with HCFC insulation); and solvents, coatings, and inks. In the case of refrigeration, air conditioning, and fire extinguishing equipment it is likely that products are accurately labelled, although there may be cases when the accuracy or correctness of the labels would be doubtful. There is no existing international labelling of products containing HCFC insulating foam or solvent ingredients.

A list of products potentially containing significant quantities of HCFC solvents includes:

adhesives,
aerosol cleaners used for electronics and precision cleaning
coatings, inks, and paints,
pesticides,
printer ink cartridges, and
numerous other products.

It will be very difficult to make a comprehensive list of products containing these substances, particularly if it includes products containing trace quantities since many products in trade potentially contain these substances. There is no possibility of using a product code or other simplifying practice for customs agents.

Customs officials could also identify products through laboratory testing of chemical content.

It will be no more difficult to control products containing HCFCs than it has been to control trade in listed products containing CFCs. The Protocol Secretariat may wish to report on the success of those CFC trade measures. The Panel and its Technical Options Committees (TOCs) have no information on whether CFC trade measures have been enforced or on whether trade measures helped reduce consumption of CFCs. In addition, in view of the slow pace of ratification of the Copenhagen Amendment, trade restrictions on products containing HCFCs could lead to increased trade among non-Parties in products containing CFCs.

4.1.3 Products Made-With But Not Containing HCFCs

Products that can be "made-with but not containing" HCFCs include: electronic components and assemblies; aerospace, aviation, audio, computer, medical, video, telecommunications, and weapons electronics equipment; and products and machinery containing electronics equipment (aircraft, automobiles, manufacturing equipment, and ships).

HCFCs are also used as a "feedstock" or as a "process agent" and may be "contained" in finished products. A list of products that may contain trace quantities of HCFCs might include: non-stick coatings used for cook ware, lubricating products, and miscellaneous uses; geotextiles used in building construction; and various chemical specialty products. It is technically feasible although potentially costly to identify trace impurities in virtually all such products. Residual HCFCs are likely to be below detection limits.

HCFCs are also used as diluents to reduce explosion risk in ethylene oxide mixtures for sterilization of medical instruments and medical products. It is not technically feasible to identify these products as made with HCFCs through laboratory analysis, as residual levels are likely to be below detection levels.

4.2 Technical and administrative feasibility of possible trade measures to Methyl Bromide

4.2.1 Methyl Bromide

Trade restrictions on methyl bromide between Parties and non-Parties could lead to adverse economic effects on trade, given the small number of countries which have ratified the

Copenhagen Amendment and the regulations in many countries which mandate use of methyl bromide for fumigation. These restrictions may be useful after methyl bromide controls are widespread and after most countries ratify the Copenhagen Amendment.

4.2.2 Products Containing Methyl Bromide

The only products containing methyl bromide are canisters and tanks used to transport and store the chemical prior to use as a fumigant or in industrial transformation processes where methyl bromide is used as a feedstock. The Panel has asked the Parties to clarify the definition of "bulk" shipments to avoid possible evasion of the intent of those Protocol provisions. Trade restrictions may be considered after ratification of the Copenhagen Amendment by most countries.

4.2.3 Products Made-With But Not Containing Methyl Bromide

There are four major uses of methyl bromide, apart from feedstock uses. These are as a soil treatment, as a fumigant for durables, for treatment of perishable commodities, and as a fumigant of structures and transport vehicles. These account for approximately, 70%, 16%, 8% and 3% of global use respectively.

It is not technically possible to determine conclusively if a product has been grown in methyl bromide-treated soil. However, substantially raised bromide content compared with normal levels indicate that methyl bromide may have been used at some stage on the soil, though not necessarily in the same growing season as the product in question. The situation is confounded by the presence of high natural bromide levels in some soils (e.g. some volcanic soils, some soils close to the sea), the substantial variability of natural bromide content within and between products, and the practice of leaching of soils to remove bromide ion prior to planting in many cultural systems. There is very little chance that unchanged methyl bromide, even in trace quantities will be present in products arising from soil fumigation.

Durable commodities react with the methyl bromide applied as a fumigant. If analyzed soon after fumigation, typically not more than a few days, trace quantities of methyl bromide may remain at sufficient levels to be detectable directly. After this, methyl bromide can be detected in the form of fixed bromide ion residues and methylated materials in the commodity. Elevated bromide ion levels above normal levels are indicative, though not conclusive, of methyl bromide treatment. Detection of high levels of methylated products (e.g. S-methyl methionine) in addition to high bromide levels would confirm the use of methyl bromide, but standard tests are not available for these methylated materials.

Perishable products are normally treated as part of quarantine or pre-shipment procedures. It is technically and administratively feasible to identify products that are fumigated with methyl bromide to meet quarantine requirements since such shipment requires an official verification of how pests are eradicated.

In summary, there are likely to be few occasions where the use of methyl bromide can be conclusively proven in "products made with, but not containing methyl bromide". However, unusually high levels of bromide ion in product are indicative that methyl bromide may have been used.

5 Developing countries and countries with economies in transition (CEIT)

5.1 Developing Country Aspects

5.1.1 Introduction

As the phaseout approaches in developed countries, the implementation process in developing countries is becoming more relevant. This chapter presents information to help in the discussion of developing country issues related to the implementation process and informs the Parties of the aspects that may hinder the implementation effort.

The points of concern include:

- availability of ozone-depleting substance (ODS) to supply developing country basic domestic needs at affordable prices;
- the impact of developed country phaseout on the cooperative approach to the transfer of technology to developing countries;
- the importance of maintaining the developed countries' commitment to achieve global phaseout of ODS in developing countries;
- the adequacy of the political and financial support for the Multilateral Fund of the Montreal Protocol;
- the importance of coordination among implementing agencies;
- the need of developing countries to be prepared to accept new technologies and having an institutional framework that will not delay access to the Multilateral Fund;
- the barriers to information exchange;
- feasibility of an early phase out of ODS in developing countries; and
- the need to regain the impetus towards phaseout that was discouraged by the granting of the 10 year grace period to implement the control measures.

5.1.2 Availability of Supplies

Developing countries that are currently producing ODS are Brazil, Argentina (distillation only), People's Republic of China, India, Mexico, Republic of Korea, Romania and Venezuela. In most cases production occurs through directly owned subsidiaries of American, European and Japanese chemical firms.

Total consumption of controlled substances in Article 5(1) countries, covered by the 40 approved country programs submitted to the Multilateral Fund as of July 1994, amounts to about 130,000 ozone depletion potential (ODP) tonnes which is a significant proportion of the total consumption of ODS in developing countries. The total Article 5(1) ODS production amounted to approximately 71,000 tonnes, therefore a clear deficit situation is envisaged if developed countries halt production. There will be no shortage if producers in developed countries rationalize their production and continue production to supply developing countries as provided for by the Protocol. In order to produce chlorofluorocarbons (CFCs), producers need carbon tetrachloride (CTC) as feedstock (80,000 tonnes were estimated to be needed to cover 1991 production figures in developing countries).

China, India and Brazil plan to continue to produce CFCs (mainly 11 and 12). Producers in Brazil have made a voluntary agreement with the industry associations to supply for the country's basic domestic needs during the implementation phase. Brazil also produces HCFC-22 and HFC-134a. The price of CFCs in India is still low and there is no incentive to recycle them. China has plans to introduce HFC production, funded by the Multilateral Fund and convert CFC to HCFC production. All current CFC producers can convert to HCFC production (such as CFC-12 to HCFC-22) provided the relevant feedstocks are available.

The refrigerants needed by Article 5(1) countries in 1995, will probably not be supplied from the recycled substances from developed Parties. Therefore, shortages may occur in developing countries. Exports of recovered refrigerants would change the retrofit and replacement pattern in the developed world. Reinvestigation of recovery and recycling in 1995 and 1996 is recommended.

Full recovery and recycling of CFCs from existing stock of foam is logistically and technically difficult.

One aspect that can divert ODS supplies from developing country users is the fraudulent smuggling of newly produced CFC described as recycled. These shipments are primarily from Eastern Europe and developing countries where production facilities are still operating.

CFC-113 is produced primarily as a solvent with small amounts sold as feedstock for production of HFC-134a and some plastics. When CFC-113 sales for solvent use stop in the European Union (EU) in 1995 and in all developed countries by 1996, the market may not be sufficient for developed country manufacturers to continue to supply developing country markets. CFC-113 is currently manufactured in two developing countries, China and India; the production facilities in the Republic of Korea and Taiwan are believed to be inactive at present.

At least 20 percent of 1,1,1-trichloroethane is produced as feedstock for HCFC-141b and HCFC-142b. Therefore, it will be more readily available than CFC-113 after 1996 for export to developing countries for their domestic needs, subject to Protocol restrictions. Quality grades of CFC-113 and 1,1,1-trichloroethane will be in uncertain supply after 1996 and it will be prudent for enterprises in developing countries to move quickly to reduce and eliminate dependence on these chemicals when cost-effective options are available. Some developed countries may have residual chemical supplies produced under national Protocol quotas or under Basic Domestic Needs quotas that may be marketed to developing countries, if sales are less than expected in their developed country markets. This oversupply is less likely in the United States where taxes on stored ozone-depleting substances discourages oversupply. It would be useful for UNEP to survey chemical manufacturers to better estimate possible sources of supply to developing countries.

Banks of halon 1211 should be sufficient to maintain critical existing equipment using recycled halon. However, for some early years after production phaseout some equipment may have to be taken out of service to provide maintenance quantities of halon 1211. It is estimated that the bank of halon 1301 will be adequate to supply existing equipment for at least 40 years after production ceases. Also it appears that recycled halon 1301 could be provided for new critical applications even after production is restricted.

5.1.3 Implementation Aspects

Country Programs

The Article 5(1) country programs are important in helping the country organize the implementation phase. They address the specific needs of each country and the actions to be taken by the various sectors and institutions in the country, as the government, the Non-Governmental Organizations (NGOs) and industry. By 1994, the Executive Committee has approved disbursements of more than US$4.8 million for the preparation of the country programs of 73 Article 5 Parties. As of July 1994, the Executive Committee has approved 40 country programs (covering 127,000 ODP tonnes, which is a significant proportion of the total consumption of ODS in Article 5(1) countries). Two more were submitted for consideration at the Fourteenth Meeting of the Executive Committee.

Projects, Training and Technical Assistance

By 1994, preparation of ODS phaseout investment projects has been completed in 17 Article 5(1) countries, which has resulted in submission and approval of 187 investments projects. Six for the foam sector(3 in Egypt, 2 in Malaysia and 1 in Venezuela), one project for the refrigeration sector (Egypt), and one for the solvent sector(Malaysia) have become operational. In total, 951 tonnes ODP of the controlled substances have been phased out. Implementation of the other 178 approved investment projects will lead to the elimination of about 41,000 additional ODP tonnes of controlled substances.

Even though the last two years have been very active as far as project preparation is concerned, remaining challenges are:

- the definition of projects in a format that can be handled efficiently by the implementing agencies;

- the levels of detail required in feasibility studies (that have proven to be a stumbling block for some Article 5 (1) countries where central government funding has traditionally been provided under less stringent conditions);
- the understanding that the Multilateral Fund is a mechanism dealing with incremental costs incurred in phaseout and not a form of general development aid;

- the mistaken idea of some governments that the estimated cost of implementing their Country Programs would be made available to them with very limited individual project definition; and

- the uncertainties over the replenishment of the Multilateral Fund in view of rising demand for funding.

Training is particularly important when introducing flammable propellants (hydrocarbons and DME) for aerosol products. Handling of these substances involves substantial risks that the workers with experience in the manufacture of CFC based aerosol products are frequently not prepared to face. The case of aerosol products illustrates how health and safety issues have to be addressed by training and technical assistance directed to developing countries. When changing to new technology, technical specifications can not always be met without proper expert assistance.

In order to have successful projects, companies must also be motivated and prepared to accept the new technology. This motivation can result from government regulation, a clearly articulated industry phaseout strategy, price increases, product shortages, or supply uncertainty for ODS.

Some technology cooperation efforts have been prematurely attempted in countries where companies and national governments were not prepared, and as a consequence little actual investment progress has been made.

Industrial Initiatives and Challenges

Industrial initiative has been responsible for a large number of successful programs to phase out ODS in developing countries. In cases with the cooperation from multi-national companies and organizations like International Cooperation for Ozone Layer Protection (ICOLP), The Japan Electrical Manufacturers' Association (JEMA), Japan Industrial Conference for Ozone Layer Protection (JICOP), and North Atlantic Treaty Organization (NATO) and with strong market incentives, ODS solvent use is rapidly decreasing.

Multinational corporations and trade associations have been key players in the Protocol implementation process. Since technology transfer, training and information need to be targeted to meet specific needs, the identification of such needs through industry initiatives has proven very efficient. Several Article 5(1) countries are part of the Protocol and phaseout process due to the pressure exerted by their local industry.

Progress has not always been made even in cases where ODS substitutes and alternatives are cost effective with rapid payback of investment, for instance in packaging foam, solvent elimination and aerosol products. One explanation for this is that capital is not always available even when investment is promising. Despite its toxicity, carbon tetrachloride use as a solvent remains widespread in India, Eastern Europe and Southeast Asia. Additional concern is that the manufacturers will adopt chlorinated solvents without proper occupational and environmental safety precautions. Training and information is a necessity.

Unless provided, there is no mechanism for the dissemination of alternative technologies and substances to replace methyl bromide. They are the same for developing and developed countries, but the transition to their use may be less readily carried out. Reasons are the lack of proper infrastructure, including inadequate training and extension services, and appropriate staff.

Ozone Units

The motivation and involvement of government in the country program, project preparation and the implementation process that follows is of utmost importance to a speedier phaseout and overall success.

In many countries government focal points or ozone units have not been, and some still are not, properly organized and have lacked adequate institutional support. Even now, although government participation is stronger, lack of local capacity to prepare and implement projects is delaying the implementation process.

By July 1994, funds amounting to US$8.8 million had been provided to 42 Article 5 countries for institutional strengthening to facilitate the implementation of country action plans for the phaseout of controlled substances. All of the ozone units that have been supported so far by funds made available to them from the Multilateral Fund (MF), are either operating or at the final stages of becoming operational.

Ozone units must have sufficient dedicated staff, funding, and regulation authority to accomplish their objectives. The resource requirements depend on the special circumstances of the particular country.

Multilateral Fund assistance is necessary for coordination and monitoring purposes but may not be efficiently used if governmental institutions do not provide sufficient priority and support to their work.

Awareness and Information Exchange

It is a necessary prerequisite that both industry and government be prepared before real progress in phasing out ODS can be achieved. Information is important, but it must be cost effective, streamlined, and targeted to meet the needs of users in developing countries.

Government Ozone Units have a coordination role and must have information to fulfil their needs. It is important that information is supplied in their own language to avoid delays and misinterpretation. They have to understand the main issues under discussion in the international scenario and be prepared to act in the decision making process. They have to be linked to the various industry sectors, NGOs and key players in the Protocol implementation process.

Enterprises need an increased understanding of the requirements of the Montreal Protocol and the time scale that they have in which to convert to non-ODS. They need to be able to identify and take advantage of local expertise and leverage the expertise of the Implementing Agencies consultants when they come to their country for project development purposes.

The general public needs simple, direct information on the science and effects and technology aspects of ozone layer protection, on how the Protocol will effect their everyday life, and how they can join the global commitment to save the ozone layer.

As we move forward with the implementation of the Protocol, adequate information is even more important. The TEAP encourages increased attention to the challenges facing the information exchange services of the Montreal Protocol institutions. Changing information needs and innovation in information systems will provide opportunities to improve performance. It will be important in this context to build consensus regarding:

- the proper role of information exchange services, and
- the capabilities to identify and meet changes in user demand.

5.1.4 Possibilities for Shorter Grace Periods.

If funding remains available, the main barriers to rapid phaseout in developing countries are largely informational and administrative, rather than technical and economic. Industrial innovation has occurred more rapidly than anticipated and there has been much more rapid progress than predicted in commercializing replacements, including non-HCFC, for CFCs and halons. Technical and commercial experience, availability of non-ODS alternatives and substitutes, cost of investments in technologies, difficulties in servicing, loss of export market access, are key points to consider. It is critical to a successful phaseout that:

- the financial mechanism succeeds;
- the implementing agencies operate in a coordinated way to avoid duplication of efforts;
- technologies available are supported by adequate technical assistance and training; and
- channels for the collection and distribution of information operate to reach domestic small and medium size enterprises that use ODSs (they are often difficult to identify, may not welcome government officers and may not be easy to convince that a change is necessary. It is likely that many users will be willing to make changes when the price increases, when shortages develop, when domestic regulations are in place, or when multinational companies require suppliers to phase out).

For methyl bromide, there is the need to evaluate whether a ten year long grace period for developing countries is advisable, in view of the trade implications and possible dumping this would cause.

There is a possibility that markets in developed countries will be resistant to products that are produced with the aid of methyl bromide. Those Article 5 countries with export earnings at risk already have strong market incentives to accelerate phaseouts of export-related methyl bromide uses. In view of the potential for trade restrictions and availability of alternatives it may be argued that only a short grace period is required for methyl bromide for developing countries.

However, a grace period should be sufficiently long to make the necessary changes to disseminate and support alternatives and to allow continued uninterrupted production of those cash crops and other exports currently dependent on methyl bromide. Developed countries may wish to assure that national environmental protection legislation permits continued importation of produce grown with the aid of methyl bromide. In the end, the allowable grace period may be irrelevant if market forces and technical innovation prevail.

Progress in the different sectors has occurred at different rates. Even in those cases where ODS substitutes and alternatives are cost effective with rapid payback of investment such as aerosols, solvents, and packaging foam, progress has not always been made at the rate expected. One explanation for this is that capital is not always available even when investment is promising.

CFC phaseout for developing countries in foams will be technically feasible around the year 2000 provided that the Multilateral Fund projects are implemented without delay. It is technically feasible to manufacture aerosol products without using CFCs. Phaseout has been successful in a number of developing countries in some cases in the same time-frame as developed countries. The main reasons for continued reliance on CFCs is the lack of suitable hydrocarbon aerosol propellants and the fragmentation of the aerosol products industry in many small producers that are unable to comply with the safety precautions needed to use flammable propellants. Some industry rationalization may be necessary in these cases and some countries with very small markets will have to do without a national aerosol products industry.

Early phaseout of halons is feasible provided that critical needs of developing countries are supplied from the existing banks and from the future banks being organized in developing countries, and that suitable import and export regulations are in place.

Early phaseout of CFC chemicals in refrigeration, which are used to service existing equipment, may imply the involvement of higher costs, unless there are proven procedures for retrofit, and/or stockpiled CFC material is available for service. If this is not the case, the remaining service life of the equipment (that may be up to 25-30 years) will, for a large part, determine the costs involved. In certain cases, where equipment with considerably higher efficiency is available, compared to 10-20 years ago, early replacements may be cost-effective and positive with regard to chlorine emissions.

Methyl bromide is produced in small (less than 1,500 tonnes) quantities in both India and China. There is concern that supplies of methyl bromide to developing countries may be curtailed if phaseout or other restrictions are imposed in developing countries. Since there is no possibility of significant supplies from recycled material, it will be necessary to secure newly produced material during any agreed transition period. Developing countries used about 14,000 tonnes (18%) of the 75,000 tonnes of methyl bromide supplied globally in 1992. Most of this was used for soil fumigation (about 70%), almost entirely for production of cash crops for export. About 20% of use in developing countries is for in-country protection of grain stocks and also for treatment of some exports (eg. rice, timber).

With shortage of supply of methyl bromide it can be expected that its price will eventually rise significantly, though historically the price of ODS temporarily falls after phaseout or restriction is agreed in developed countries. The voluntary Food and Agriculture Organization (FAO) Code of Practice for Producers of Pesticides states that pesticides severely restricted or banned in a producing country should not be exported to developing countries. Application of this principle could restrict supply to developing countries, independent of Protocol requirements.

5.2 Countries with Economies in Transition Aspects

Since the signing of the Montreal Protocol and its London Amendment substantial changes occurred in the countries of the Central and Eastern European region and on the territory of the former Soviet Union. As a consequence of the dissolution of the former Soviet Union, as well as the former Yugoslavia, a number of new independent states emerged. The transition from the "planned economy" political regime to market economies has begun, but is taking much more time than thought and hoped for.

The Montreal Protocol had been ratified by the following states by 1991 when the transition began:

1988	Belarus
1990	Bulgaria
1989	Czech and Slovak Republic
1989	German Democratic Republic
1989	Hungary
1990	Poland
1988	Soviet Union
1988	Ukraine
1991	Yugoslavia

Romania ratified the Protocol in 1993, Albania (Central and Eastern Europe) and Mongolia (Asia) as former planned economy countries have not signed the Protocol.

All the countries of this region--with the exception of Romania and Yugoslavia--were classified as non-Article 5 countries. Since 1991, some of these countries requested a new categorization of countries, i.e. those non-Article 5 countries with economies in transition but, in the context of the Montreal Protocol, have not succeeded. Similar efforts have been partially acknowledged by the Rio UN Conference on Environment and Development in 1992.

By 1992 the following states existed in the region:

Successor States to the former Soviet Union:

> Armenia, Azerbaijan, Belarus, Georgia, Kazachstan, Kyrgizistan, Moldova, Russian Federation (continuing the membership of the former Soviet Union), Tadjikistan, Turkmenistan, Ukraine, Uzbekistan;

Baltic States:

> Estonia, Latvia, Lithuania;

Central and Eastern European States:

> Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia;

Successor States to the former Yugoslavia:

> Bosnia-Herzegovina, Croatia, Slovenia, the former Yugoslav Republic of Macedonia, Yugoslavia (Serbia and Montenegro).

Of all of these states, Belarus, the Russian Federation, Turkmenistan, Ukraine, Uzbekistan, and all the Central and Eastern European states as well as the successor states to the former Yugoslavia are Parties to the Montreal Protocol; the London Amendment has been ratified by the Russian Federation, Turkmenistan, Hungary, Romania, Croatia and Slovenia; the Copenhagen Amendment by Hungary.

Production and consumption data in CEIT

The production of ozone-depleting substances in Central and Eastern Europe has been concentrated in the former Soviet Union (CFCs and halons), now in the Russian Federation, with minor CFC production in the Czech Republic (approx. 2000 tonnes per year) and Romania. It is reported that there was production of methyl bromide in the Ukraine of about 2000 tonnes in 1992. All other countries are consumers, but not producers of ODSs.

No official production and consumption data are available for the successor states to the former Soviet Union and the Baltic republics; the former Soviet Union reported the production and consumption data for the years 1986, 1989, and 1990. An assessment of the consumption is being done in the framework of the Country Programme for the Russian Federation, as well as in the Country Programmes for the Baltic Republics. The baseline level of consumption of CFCs and halons was in the order of about 150,000 tonnes per year.

Legislation and institutions

In many of the successor states there is no legislative basis to ratify and implement the Montreal Protocol and there are no institutions/authorities to manage the phaseout of ODSs or even to report consumption data and to establish the baseline consumption level. In a number of states (e.g. the Baltic republics) the accession to the Protocol as amended in London is difficult because of the country's classification as non-Article 5 which includes the obligation to contribute to the Multilateral Fund. Fortunately, the Central European states, probably including Slovenia, have both the necessary legislation and administrative capabilities to govern the phaseout of ODSs.

Status of countries with economies in transition (CEIT)

All states of the Central and Eastern European region as well as Commonwealth of Independent States (CIS) states are struggling with the difficulties of the transition from a planned economy to market economy, the world-wide recession, market discrimination and exclusion, and with high inflation rates and chronic lack of capital, even for investments with short payback time. Their resources are mostly inadequate for a timely ODS phaseout. The phaseout of the production in the Russian Federation is an additional problem. The reduction of the consumption of ODSs in the Central European states has been a consequence of decrease in industrial output due to the factors referred to earlier, and only partly as a result of actual phaseout activities and investments.

Possible cases of non-compliance

It seems inevitable that non-compliance will occur in several states. The interruption to industry caused by political changes, coupled with lack of finance and appropriate infrastructure means that transition to non-ODS use will not occur by 1996.

The TEAP wishes to draw the attention of the Parties to the problems of countries with economies in transition, which did not exist when the Montreal Protocol and its London amendment were signed.

In the 1995 March Report a more detailed description of the problems and possible approaches to solve those problems will be presented.

6 Summary of the Report of the Aerosols, Sterilants, Miscellaneous Uses and Carbon tetrachloride Technical Options Committee

6.1 Aerosol Products

Chlorofluorocarbons (CFCs) have been used extensively in aerosol products as a propellant but also as the solvent or active ingredient. In 1989 some 180,000 tonnes of CFCs were used worldwide in aerosol products. It is believed that in 1992, this volume probably dropped below 80,000 tonnes, a reduction of some 220,000 tonnes since 1986. Substantial work is being carried out to reformulate the products which still use CFCs. In countries which have implemented phase out programs, the remaining aerosol product uses are principally in the pharmaceutical sector.

There are a variety of alternatives available to substitute CFCs in virtually all aerosol products. The optimal alternative depends on the specific product under consideration. Each alternative has its own unique set of properties which need to be taken into account. These include toxicity, environmental impact, flammability, solvency, performance characteristics and cost. The alternatives currently available include hydrocarbons (hydrocarbon aerosol propellants, HAPs), dimethyl ether, compressed gases, HCFCs, HFCs, non-aerosol delivery systems and product substitutes.

A large majority of non-medical aerosol products have already or are likely to be replaced with hydrocarbons. This requires reformulation, retrofitting and sometimes relocation of the manufacturing facility. The use of hydrocarbons requires precautionary measures to be taken during production, storage and transportation to prevent fire and explosion. Generally it has taken about one to three years to convert plant and formulations. In some countries this process is well under way. In others, serious problems exist in obtaining the quality of hydrocarbon feedstock required to be purified as HAPs. The de-stenching purification process is costly and may require sophisticated technology.

Dimethyl ether is another alternative propellant. It is flammable, is more expensive than hydrocarbons and requires care when formulating aqueous products in tin plate cans to avoid corrosion problems. It is an excellent solvent which is soluble in water up to 35% which provides interesting formulation possibilities, however, because of its solvency it requires special seals and gaskets for filling equipment and aerosol valves.

HFC 152a is another flammable propellant which has been used in mousses because it produces an excellent foam and as a non volatile organic compound (VOC) its use is increasing, particularly in the USA.

Currently available non-flammable propellant substitutes include compressed gases (such as CO_2 and N_2), HCFC 22, alone or in mixtures and HFC 134a. It must be noted that the use of a non-flammable propellant may not yield a non-flammable aerosol product.

Compressed gases have been used as propellants for a long time and currently comprise nine percent of the aerosol product market. They produce poor quality sprays and therefore, their use is, therefore, limited to crawling insect insecticides and other products for which a wet spray is acceptable.

Because of their price and potential for ozone depletion, HCFCs have found limited and temporary application. HCFCs, therefore, have not made a significant contribution to the reduction of CFCs in this sector. The volume of HCFCs currently in use is expected to decrease significantly over the next few years.

HFC 134a is commercially available and is used principally in aerosols where product flammability is a concern. Other new fluorine based chemicals such as HFC 227 and 125 are under consideration and development. Their cost will be higher than that of HFC 134a which may limit applications. Additional toxicological studies of these substances must also be completed.

Non-propellant alternatives can also be used to apply or administer some products which currently utilize CFCs. These include devices such as finger pumps, trigger pumps and mechanical pressure dispensers.

There are a number of products in the non-inhalant medical aerosol and technical specialty area where CFCs are still used and are classified essential under legislation in many countries. The quantity and likelihood of these products requiring continued use of CFCs is limited in developed countries.

A few essential use production/consumption exemption nominations for non-inhalant medical aerosol products were forwarded to this committee for review. At the time of writing the committee was unable to recommend that these uses be exempted from the I January 1996 ban on production of CFCs.

In conclusion, in developed countries (excluding eastern European countries), the use of CFCs in non-medical aerosols has been reduced to less than 20,000 tonnes per year. A significant volume of CFCs is still used in a range of aerosol products in some developing and eastern European countries. The major impediment to conversion in these countries is a lack of availability of hydrocarbons, lack of technology awareness and lack of adequate financial assistance to complete the conversion process. In developing countries, the speed of conversion has, therefore, not been as fast as was indicated in the 1991 assessment. Therefore, the expected reduction of total CFC use in aerosol products to some 15,000 tonnes worldwide by 1995 is unlikely to be achieved.

6.2 Medical Aerosol Products

Within the category of aerosol products, specific oral inhalants for pulmonary diseases are recognized as the most difficult to substitute. Other medical aerosol products include nasal preparations, anti-anginal sprays, local anaesthetics, wound sprays, antibiotics, antiseptics and ancillary products.

These products do not require the properties considered necessary for oral inhalers, therefore they could be reformulated either through the use of alternative propellants, mechanical pump sprays or the use of powders, creams and other liquids.

The prevalence of asthma and chronic obstructive pulmonary disease (COPD) is increasing worldwide. It is estimated there are at least 300 million people with asthma world wide and may be as many again with COPD. The prevalence of asthma in children is at least 10% in developed countries. In adults, asthma affects at least 6% of the population. Asthma deaths are largely preventable and related to undertreatment.

There is international consensus that primary treatment of these diseases should be by the inhaled route. This permits treatment to be delivered quickly and efficiently to the lower airways, with minimal risk of adverse reactions. Therapy necessitates regular treatment, often with more than one drug. Inhaled therapy can be administered to airways by a variety of means such as nebulisers, metered dose inhalers and dry powder inhalers.

As a consequence of the above factors, there is an existing and increasing requirement for inhaled medications.

This is largely met by CFC driven metered dose inhalers (MDIs), which are cheap, reliable and effective therapy. MDIs currently use CFC 12 as a propellant and most use CFC 11 and 114 either alone or in mixture to suspend or dissolve medication.

Alternatives to MDIs include tablet therapy (cheap, easy to use but with greater potential for side effects than MDIs) nebulised therapy, (expensive, not easily portable, requires an external power source) and dry powder inhalers. Dry powder inhalers (DPIs) are effective, easy to use, portable and available in multi-dose formulations but may need special packaging in humid climates and are dependent on adequate inspiratory flow.

Available dry powder inhalers are not suitable for all young children or certain adults. Dose for dose they may also be more expensive than MDIs and not all products are available as DPIs in all countries.

An intense technical development of dry powder inhalers is going on, which might further enhance the possibilities for this non-CFC alternative. There was a relative increase in the global use of dry powder inhalers of about 5% between 1990 and 1992, reaching approximately 15% of inhaled medicines in 1992.

Compressed gases, hydrocarbons, HCFCs and HFCs have been evaluated as potential alternatives to CFCs for inhalant drug products. All alternative propellants have proved unsuitable other than HFCs. HFCs 134a and 227 appear suitable for use in MDIs. Toxicological studies have reached an advanced stage and will, in the case of HFC 134a be complete during the first half of 1994 and for HFC 227, the first half of 1995. Concurrent with this work, pharmaceutical product development programs are proceeding and early dosing of humans is under way. Clinical studies on the more easily reformulated drug products have commenced and a succession of new formulations will follow as technical difficulties are resolved.

Given the duration of the clinical studies required to demonstrate equivalent efficacy and safety, the time required for review of the extensive documentation needed to describe these findings and to confirm product quality by each national regulatory authority, it is unlikely that alternative MDIs will be available until 1996. It is envisaged that the bulk of the transition to non CFC inhalation products will occur in the late 1990s.

In 1992 use of CFCs for MDIs was estimated to be 7,000-8,000 tonnes. Essential use production exemption nominations for 1996 total 13,000 tonnes. These figures are compatible with the 1991 predictions. This predicted increase in MDI / CFC usage is due to the following;

- data for 1992 were likely to be incomplete.
- there has been a significant increase in the detection and prevalence of airway diseases, and
- international guidelines have accentuated the change from tablet treatment to inhaled therapy, and encouraged the greater use of regularly used inhaled treatment.

In developing countries the current use of inhalant drug products is comparatively small, but there is likely to be an increasing need for these products over the rest of the decade. The use of these inhaled drugs will be increased by a number of factors including the widespread adoption of international guidelines on asthma management by physicians, increasing disease prevalence and economic factors. The likely extent of increased use of these products is substantial but unpredictable.

Prediction of use of inhaled drug products over the next 10 years is compounded by several variables. The two major diseases necessitating use of inhaled drugs are both increasing in frequency. Medical management of those diseases is also increasingly favouring the inhaled route of administering drugs. It may be appropriate for some of that usage to be provided by an increased use of dry powder inhalers, but for reasons of availability, drug choice, storage and cost, the CFC driven metered dose inhalers are likely to remain the commonest method of inhaling medicines for at least the next 3 years. Toxicological testing of CFC replacement propellants, clinical trials and approval in many different countries is a time consuming process. It may be possible for regulatory authorities to expedite some aspects of the review process.

Patient requirement for CFC driven MDIs is likely to increase on current estimates by about 10-20% per annum for the next 3 years. Thereafter a decline can be anticipated consequent to the introduction of CFC free MDIs and wider use of DPIs. If these predictions are an underestimate and production of CFCs is limited as a result, undesirable health impacts are likely for the percentage of patients with asthma and COPD unable to use alternative therapies. Adequate CFC supplies should therefore be maintained during this transition period.

6.3 Sterilants

A mixture of CFC 12 and ethylene oxide (EO) is widely used for gas sterilization of medical equipment and devices. EO (the sterilizing agent) can be used in a one hundred percent form (termed 100% EO) or diluted with other gases. EO has the ability to penetrate a wide variety of packaging materials. This attribute is vital to the handling, storage and transport of medical equipment and devices prior to use. EO is especially useful for sterilizing heat and moisture sensitive products such as plastic catheters, electrical devices and non metallic implants. EO is toxic, mutagenic, a suspected carcinogen, flammable and explosive. The use of 100% EO, therefore requires stringent safety precautions.

To reduce flammability and explosion risks, EO is diluted with CFC 12 to form a mixture of 12% (by weight) EO and 88% CFC 12 (commonly known as 12/88) which due to its potential health hazards must also be used with great care.

The total use of CFC 12 worldwide for sterilization was estimated to be approximately 18,000-20,000 tonnes in 1991. In 1992/93 there was an estimated volume of 8,000-10,000 tonnes used.

Many medical device manufacturers and contract sterilization services have elected to invest in the equipment necessary to use the explosive and flammable mixtures or radiation sterilization facilities. These users strive to optimize economically their processes because they process many identical items either serially or together, and can customize the process to the product. Health care facilities (hospitals) batch process many different re-usable items in the same sterilizer load. This requires a broadly effective sterilant tolerant of processing error by personnel.

Alternatives available to health care facilities include: small volume 100% EO sterilizers operating with sub-atmospheric conditions, pressure vessel rated chambers using a mixture of EO/CO_2, and a newly developed mixture of 8.6% EO and 91.4% HCFC 124. These are all commercially available to the health care community on a world-wide basis. Some existing 12/88 equipment can be converted to the EO/CO_2 mixture. Most existing equipment can convert to the EO/HCFC 124 mixture. (100% EO in large sterilizers in USA hospitals is not possible due to extreme risks of flammability and explosion. All regulatory agencies prohibit such use since the sterilizer must be located near the operating rooms or central supply).

Industrial options include the use of 100% EO, mixtures of CO_2 or nitrogen and EO, mixtures of EO and HCFC 124 and radiation sterilization. At this time most industrial users have already eliminated 12/88 in the developed countries. Many industrial and commercial users of 12/88 have converted existing sterilization chambers to 100% EO. Such a conversion, however, requires extensive and costly retrofitting for safety, possible relocation within the plant or construction of a new facility.

In countries where formaldehyde is accepted, heat and moisture tolerant devices can be sterilized with formaldehyde, leaving a small number of devices requiring EO sterilization. These can be sterilized either at hospitals with 100% EO in small sterilizers; or, by the manufacturer; or, a third party sterilizing facility.

Devices which are heat and moisture sensitive such as catheters and some fibre optics require EO, alone or in mixtures with CO_2 or HCFC 124. HCFC 124/EO, a drop in substitute, will allow hospitals to keep in operation their existing sterilization units. The material cost of the HCFC 124/EO may be considerably higher than 12/88, particularly in those countries where CFCs are not being taxed.

Systems available for recovery and recycling of CFC 12/EO can also be used for the recovery and recycling of HCFC/EO mixtures. These systems are quite complex and expensive, however, with the higher prices of substitute diluents, recovery systems may offer an attractive economic payback for industrial or large hospital users.

12/88 is used to some extent in at least 60 countries. Many countries have scheduled the phase-out of 12/88 or have accomplished the ban of CFCs for sterilant use. There are some countries where CFCs have already been banned in the hospital environment, for example Chile has banned CFCs and has converted to EO/CO_2.

In conclusion, by using a combination of existing techniques, the current use of CFC 12 for sterilization can be phased out not later than 1995 in developed countries. The high cost of the drop-in replacements and availability of technology, appropriate expertise and training could increase the timescale of conversion of 12/88 equipment in developing countries.

6.4 Miscellaneous Uses

CFCs are or have been used for a variety of miscellaneous uses such as food freezing, tobacco expansion, leak detection, graphite purification, solar tracking systems and as a dielectric fluid in linear accelerators for cancer treatment. CFCs are used in laboratory procedures, for example, standard methods for analyzing oil require the use of CFCs or carbon tetrachloride (CTC). New standard methods are therefore required to avoid the use of ozone depleting substances.

The miscellaneous uses mentioned in this report are believed to consume, on a global basis, only a very small volume of CFCs. It is important, however, to be aware of these and other miscellaneous uses when considering the new Montreal Protocol phase out schedule and whether any of these areas are critical to health, safety and the functioning of society.

Other than most laboratory uses of ODS, many of the identified miscellaneous uses should be able to be substituted by alternative fluorocarbons or other available technologies.

6.5 Carbon Tetrachloride

The primary use of carbon tetrachloride (CTC) is as a feedstock for the production of CFC 11 and 12. As the use of CFCs is phased out, the production of CTC will also be progressively reduced by means of plant closure and in many cases by switching production units to other uses.

There are some other feedstock uses of CTC which are allowed under the Montreal Protocol and are regarded by industry as essential. These include its use as a feedstock material for production of key pharmaceutical and agricultural chemicals, and as a catalyst promoter (sweetener) in oil refineries. Some key research and development applications use CTC as a reagent. In these applications CTC is destroyed.

Inadvertent production of CTC will continue to a limited extent, as CTC is a by-product in many chlorohydrocarbon production complexes. The majority of this material is recycled or consumed within the production complex.

It is essential to understand the distinction between allowable feedstock uses (where CTC is chemically transformed or destroyed) and dispersive uses (such as use as a process solvent where CTC remains unchanged). CTC is toxic and is designated as a 'possible' human carcinogen in many countries and its dispersive use is limited.

The main dispersive use is as a solvent for materials undergoing chlorination, the majority being used in the production of chlorinated rubber and small quantities being used as a process solvent in pharmaceutical manufacture. In order to find alternatives, each chlorination reaction has to be evaluated.

In many cases the use of best practicable control technology, recovery and recycling and the destruction of residues can reduce emissions to insignificant levels and render the process virtually non-dispersive.

Where CTC is used as a process solvent in the pharmaceutical industry, alternatives could require extensive approval over a 5-7 year time frame. In cases where alternatives cannot be found or the time frame for approval is lengthy, continued use may be required with appropriate recovery/recycling controls.

There are a number of important laboratory applications which will be difficult to replace, for example, as a solvent for infra-red analysis of oil samples. There are many standard analytical methods which specify the use of CTC and will require the identification of alternatives and the alteration of the standard by the relevant national or international authority.

The committee has found there has been limited effort into evaluating and developing alternatives, largely because there are a large number of small users who are difficult to identify. Of the analytical uses recently identified, few alternatives have been found. This is an area which requires education and information dissemination.

A number of essential use production/consumption exemption nominations were forwarded to the committee for review. These include the use of CTC in the production of chlorinated rubber, chlorine and terephthaloyldichloride as well as analytical uses. For further information on the committee's review of these nominations see the Technology and

Economic Assessment Panel Report March 1994, or the relevant Technical Options Report. It is recognized CTC is used in some countries as a cleaning solvent. Alternatives for this application are widely available. Reference should be made to the UNEP Solvents Technical Options Report for clarification of its use and options for substitution.

6.6 Summary of technical options either under consideration or currently used

These options for reduction or substitution of controlled substances will be dependent on the specific application.

Sector	Options
Aerosols	Hydrocarbons (HAPs)
	Dimethyl Ether(DME)
	Compressed Gases, CO_2, N_2, N_2O, Air
	HCFC 142b/ 22
	HFC 152a/ 134a/ 227ea
	Pump Sprays
	Solid Sticks
	Roll-ons
	Brushes/Pads/Shakers/Powder
	Nebulizers
Inhalant Drug Products	HFC 134a/HFC 227
	Dry Powder Inhalers
Sterilants	Steam Sterilization
	100% Ethylene Oxide
	CO_2/EO (10/90) and other CO_2 mixtures
	Formaldehyde
	HCFC 124/EO
	Gas plasma
	Vapour phase hydrogen peroxide
	Gaseous Ozone
	Chlorine Dioxide
	Gamma and Electron Beam Radiation
	Off-site Sterilisation
	Recovery/Recycling
Carbon Tetrachloride	Recovery/Recycling
	Other Solvents (eg. trichloroethylene, methylene chloride and perchloroethylene)
Miscellaneous Uses	
Tobacco Expansion	Liquid CO_2
	Propane
Freezants	Cryogenic methods (liquid N_2, CO_2)
	Air blast freezing
	Different approach
Analysis of Hydrocarbons	Other Solvents
	Hexane
Dielectric Medium	Sulphur Hexafluoride

7 Summary of the Report of the Flexible and Rigid Foams Technical Options Committee

7.1 Key Conclusions

- In 1993, the foam plastics industry reduced CFC consumption by 50% since 1986, despite a 45% increase in the size of the foam market over that period.
- Zero ODP alternatives are the substitutes of choice in many applications including packaging, cushioning and certain rigid thermal insulation foams.
- In several markets and for certain applications HCFCs are necessary for rigid thermal insulating foams and automotive integral skin foams until zero ODP solutions are proven including high energy efficiency or properties required for safety.
- CFC phaseout for developing countries is technically feasible around the year 2000 provided that Multilateral Fund projects are implemented without delay.
- The main zero ODP solutions still to be proven are liquid HFCs. In addition, broader qualification of hydrocarbons is also required. This situation is likely to be resolved around the year 2000.
- Once zero ODP solutions have been proven, and are commercially available, the implementation can be relatively rapid (3-5 years) for foam manufacturing in developed countries.
- Full recovery and recycling of CFCs from the existing stock of foam is logistically and technically difficult.

7.2 Summary of CFC Reduction in Foams Sector Since 1986

Historically, the fully halogenated chlorofluorocarbons (CFCs) used by the foam plastics manufacturing industry have been extremely varied. An assortment of CFCs, such as CFC-11, CFC-12, CFC-113 and CFC-114, and methyl chloroform, have been used in numerous foam plastic product applications. The types and major applications of foams which used CFCs are summarised in Table ES-1.

Table ES-1 Major Applications and Types of Foam Which Used CFCs

INSULATION	Construction	Polystyrene	Boardstock
		Polyolefin	Pipe
		Rigid Polyurethane	Boardstock/Flexible Faced Laminates
			Sandwich Panels
			Spray/Pour-in-Place
			Slabstock
			Pipe-in-Pipe
		Phenolic	Board
			Pipe
	Appliance	Rigid Polyurethane	Refrigerators/Freezers
			Picnic Boxes/Other
	Transport	Rigid Polyurethane	Sandwich Panels
		Polystyrene	Sandwich Panels
PACKAGING	Sheet	Polystyrene	Single Service Uses
			Food Packaging
			Misc. Packaging
		Polyolefin	Furniture
			Cushion Packaging
	Non-Insulation Rigid	Polyurethane	
	Moulded	Polyolefin	Cushion Packaging
	Boardstock	Polyolefin	Cushion Packaging
CUSHIONING	Slabstock	Flexible Polyurethane	Carpet Underlay
			Furniture
	Moulded	Flexible Polyurethane	Furniture
			Carpet Underlay
			Automotive Cushioning
			Auto Bumper Systems
SAFETY	Moulded	Polyolefin	Auto Bumper Systems
	Integral Skin	Polyurethane	Steering Wheels/Headrests
	Sheet	Polyolefin	Flotation - Life Vests
	Board	Polyolefin	Flotation
		Polystyrene	Flotation

This report details the available technical options that can be implemented by each foam type to eliminate CFC usage as of 1994. Updates on the progress of each product in reducing CFC consumption since 1986 (summarised in Figure ES-1) are also provided.

It should be noted that specific technical options and the extent of CFC reduction achieved to date vary depending upon the foam application, market sector and applicable energy efficiency requirements. Consequently, key factors affecting the total elimination of ozone depleting substances from the foam plastics manufacturing industry are also discussed.

Overall, significant progress has been made in phasing-out CFCs in the foams sector. The foam plastics industry has reduced total CFC consumption by 50% since 1986, from 267,000 tonnes in 1986 to 133,000 tonnes in 1993. Globally, CFC consumption has either been reduced or eliminated in every market sector since 1986, despite a 45% increase in the size of the industry over the last eight years.

Reductions have been achieved by CFC conservation, product reformulation, direct substitution of CFCs with other blowing agents, not-in-kind substitutes or the use of new manufacturing technologies. In general, the greatest reductions in CFC consumption have been achieved by developed nations. For the developed countries the transition out of Annex A, Group I substances will essentially be completed in 1994, except limited use for rigid polyurethane foams for home appliance insulation. As discussed later, developing countries also are working to achieve similar CFC reductions and may not require the additional time to phaseout that the Montreal Protocol allows.

There was only one essential use nomination in the sector for 1996 relating to CFC use for analytical/laboratory uses in alternative blowing agent research. The Foams Technical Options Committee, the Technology and Economic Assessment Panel and the Open-Ended Working Group were unable to recommend this nomination to the Parties of the Protocol. The Parties decided at their October 1994 meeting not to grant an essential use for foams. Given the availability of CFC substitutes for blowing agents, few or no additional essential use nominations are anticipated in the foam plastics sector.

HCFCs are the major current alternative for rigid thermal insulation foam and certain other applications. It is estimated that 60,000 tonnes of HCFCs were used in 1993. The 1993 CFC and HCFC use estimates fail to reflect the current progress being made by the foam industry to eliminate CFCs. The real transition year for phasing out CFCs in the foam sector is 1994.

7.3 Phaseout Status in Developed Countries

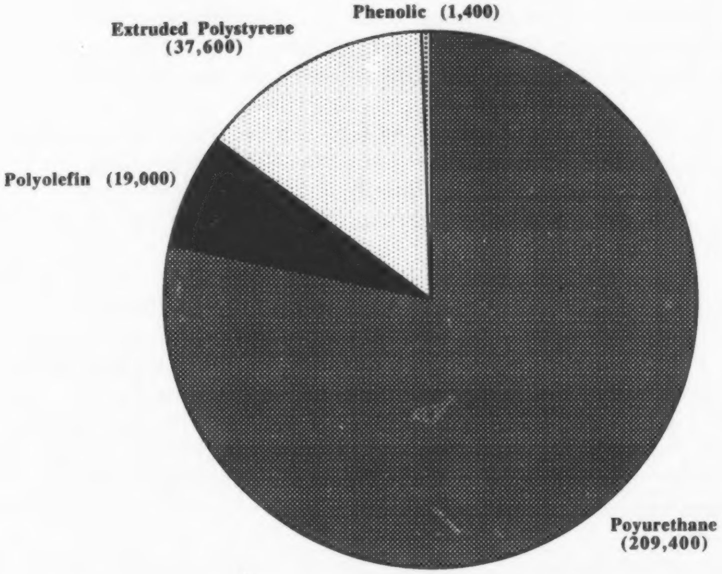
Packaging foams have completed the phaseout of CFCs.

However, in developing countries there is still over 12,000 tonnes of CFCs used for extruded polystyrene packaging products despite the widescale availability of alternatives.

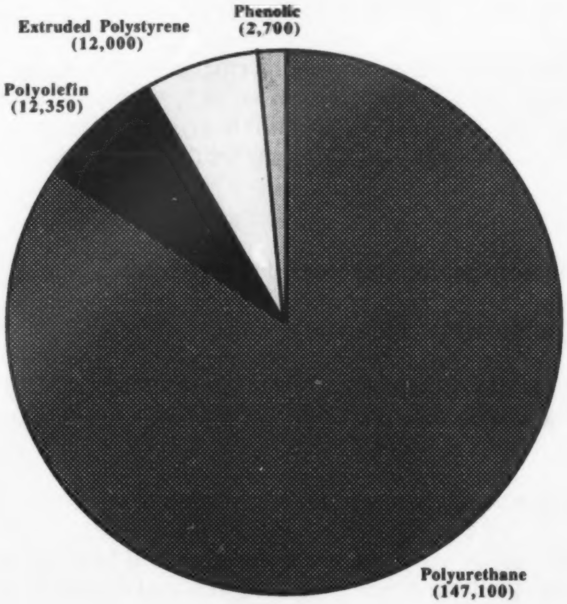
Elimination of CFCs in cushioning foams nears completion.

By end of 1994 worldwide use of CFCs in this application will have been eliminated. Continued use of CFCs are likely in developing countries and Eastern Europe.

Figures ES-1
CFC Consumption by Foam Sector
(tonnes)

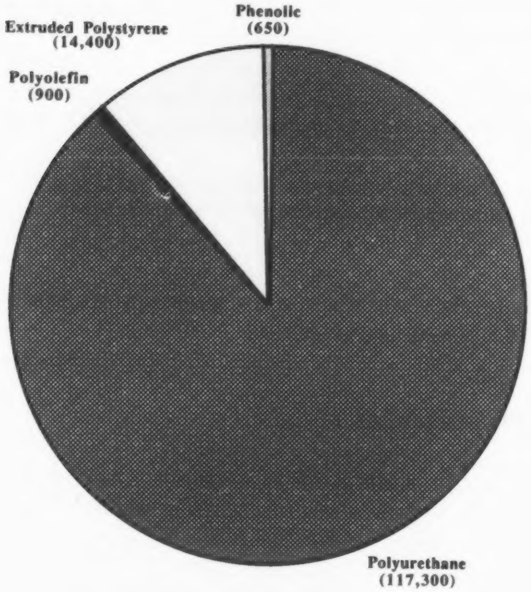


1986
(Total = 267,400 tonnes)



1990
(Total = 174,150 tonnes)

Figures ES-1 (continued)
CFC Consumption by Foam Sector
(tonnes)



1993
(Total = 133,250 tonnes)

Rigid thermal insulation foam has reduced CFC use by 45% in 1993.

By the end of 1994, CFC use will be essentially phased out, with limited use in the appliance foam sector until mid-1995.

Automotive Foams for Safety (Integral Skin) is near complete in phasing out CFCs.

Foams used for automotive safety will have virtually eliminated CFCs by the end of 1994.

Although significant progress has been made in the replacement of CFCs in foam manufacture, no single solution has emerged from the transition process. Choices must be retained to allow optimal solutions for given applications, producer-specific and country-specific circumstances. Table ES-2 outlines currently available and long-term alternatives undergoing testing.

7.4 Zero-ODP Alternatives

Zero-ODP alternatives are currently the substitutes of choice in many foam types and applications. The major zero-ODP applications are:

- polystyrene, polyolefin and polyurethane for packaging with CO_2 (injected and water), hydrocarbons and HFC-152a;
- flexible polyurethane for cushioning with methylene chloride, CO_2 (water and injected), hydrocarbons, acetone and alternative technologies;
- polyurethane and polystyrene rigid insulation foams where energy efficiency and fire safety requirements can be met with hydrocarbons, and CO_2 (water and injected);
- polyurethane integral skin for non-automotive safety applications with CO_2 (water), HFC-134a and hydrocarbons.

7.5 Transitional Substances

In several markets and for certain applications HCFCs are necessary for rigid thermal insulating foams and automotive safety integral skin foams until other long term zero-ODP solutions are proven. Given the availability of zero-ODP substitutes for other foam applications, it is unlikely that there will be expanding use of HCFCs in developing or developed countries beyond the insulation or safety foam applications.

The selection of an HCFC depends on the foam type and application. The major HCFC applications are:

Rigid polyurethane for appliance and construction with preferred use of HCFC-141b and minor use of HCFC-22/-142b blends;

Integral skin polyurethane for interior automotive safety components with use of HCFC-22;

CFC Alternatives Available to the Foam Industry

Table ES-1(A) Polyurethane Foams

Foam Type	**Current CFC Alternative**	**Long Term CFC Alternative**
Rigid:		
Domestic Refrigerators and Freezers	Reduced CFC-11, cyclopentane, HCFC-141b	HFCs (-245, -356, -365), vacuum panels, hydrocarbons
Other appliances	Reduced CFC-11, HCFC-141b, HCFC-22, HCFC-22/HCFC-142b blend, pentane, CO_2 (water)	HFCs (-245, -356, -365), pentanes, CO_2 (water), AB Technology
Boardstock/Flex-Faced Lamination	HCFC-141b, pentanes, HCFC-22	HFCs (-245, -356, -365), pentanes
Sandwich Panels	Reduced CFC-11, HCFC-141b, HCFC-22, HCFC-22/HCFC-142b blend, pentane, HCFC-134a	HFC (-245, -356, -365), pentanes, CO_2 (water)
Spray	Reduced CFC-11, pentanes, HCFC-141b	HFC (-245, -356, -365), CO_2 (water)
Slabstock	Reduced CFC-11, pentane, HCFC-141b	HFC (-245, -356, -365), CO_2 (water or injected)
Pipe	CO_2 (water), HCFC-22, HCFC-22/HCFC-142b blends, HCFC-141b, pentanes	HFC (-245, -356, -365), CO_2 (water)
Flexible:		
Slab	extended-range polyols, CO_2 (water and injected), softening agents, methylene chloride, methyl chloroform, acetone, AB Technology, increased density, HCFC-141b, pentane, MDI Technology, alternative technologies (E-Max, accelerated cooling, variable pressure)	CO_2 (injected), alternative technologies
Moulded	Increased density, methyl chloroform, extended range polyols, CO_2 (water), HCFC-141b	CO_2 (water), HFCs (-245, -356, -365)
Integral Skin		
	HCFC-22, hydrocarbons, LBL2, HCFC-22/HCFC-142b blends	HFCs (-245, -356, -365), hydrocarbons

CFC Alternatives Available to the Foam Industry (cont.)

Table ES-1(B) Phenolic Foams

Current CFC Alternative	Long Term CFC Alternative
HCFC-22, hydrocarbons, LBL2, HCFC-22/HCFC-142b blends	HFCs (-245, -356, -365), hydrocarbons

Table ES-1(C) Extruded Polystyrene Foams

Foam Type	Current CFC Alternative	Long Term CFC Alternative
Sheets	HCFC-22, hydrocarbons, CO_2 (injected), HFC-152a	CO_2 (injected), hydrocarbons, atmospheric gases, HFCs (-134a, -152a)
Boardstock	HCFC-22, HCFC-142b, CO_2	HFCs

Table ES-1(D) Polyolefin Foams

Current CFC Alternative	Long Term CFC Alternative
Hydrocarbons, HCFC-22, HCFC-142b, CO_2 (injected), HFC-152a	Hydrocarbons, CO_2 (injected)

Extruded polystyrene board for construction with preferred use of HCFC-142b and some use of HCFC-22;

Phenolic foam for building and pipe insulation with use of HCFC-141b; and Polyolefin foam for pipe insulation with use of HCFC-142b.

In 1993, it was estimated that 60,000 tonnes of HCFCs were used to help achieve the CFC reductions of 50% since 1986.

7.6 Developing Countries

Technology needs of developing countries are similar to those in developed countries except that climatic conditions can be severe and enterprises may be small.

Ozone depleting substances used in the foams sector are often devoted toward fulfilling basic societal needs such as food preservation.

The strong growth of industry in many countries makes a CFC phaseout in as short a time as is practicable, for example about 2000, a high priority so as to not increase significantly atmospheric chlorine loading. Achieving a phaseout target year of about 2000 depends on:

- quick development of country programmes
- rapid generation of individual enterprise projects which are as cost effective as possible so as to make best use of the MLF
- avoiding the use of intermediate technologies which can result in costly replacement
- making most efficient use of national institutes.
- using local alternatives where possible and provided that they are of acceptable quality
- ensuring the support of governments,
- availability of sufficient experts to speed training and technology transfer, and
- availability of equipment to handle flammable and low boiling blowing agents.

ODS replacement programmes, however, should not compromise health or safety.

7.7 Long Term Zero-ODP Alternatives

The main zero-ODP solutions still to be proven are liquid HFC isomers. There also needs to be a broader qualification of hydrocarbons. This situation is likely to be resolved around 2000. In addition to technical feasibility, qualification of these blowing agents at a minimum includes:

Safety -- Uncertainties associated with the toxicity of new substitute blowing agents and exposure to possible decomposition products formed in foams must be narrowed to ensure worker and consumer safety. Safe handling procedures required for substitutes of varying degrees of flammability must also be evaluated.

Environment -- Risks to the environment must be controllable to meet local, regional and national standards. Environmental issues include restrictions on the emissions of volatile organic compounds, such as hydrocarbons, and global warming concerns.

Product Performance -- Thermal insulation and safety products must meet market and regulatory requirements including building and fire codes, consumer/market needs, and energy efficiency requirements. It is particularly important to further qualify hydrocarbons. This is particularly important if hydrocarbons are to qualify for all products in all regions.

Cost and Availability of Alternatives -- Substitutes must be sufficiently available and affordable to allow for an orderly transition and to allow for products to be manufactured and sold competitively.

National & Regional Legislation (new or proposed) -- Transition efforts will be affected by differing national and regional legislation regulating the use of various substitutes. Legislative diversity and inconsistency can create obstacles that impede the implementation of substitutes particularly for companies serving multinational markets.

Once these zero-ODP alternatives have been proven, and are commercially available, then full implementation can be relatively rapid (3-5 years) for the foams sector.

7.8 Recovery/Recycling/Destruction

Full recovery and recycling of CFCs from the existing stock of foam is logistically and technically difficult. Where the foam can be separated from other materials, destruction of CFC and HCFC by the incineration of the foam (a destruction technology approved by UNEP) is currently the most effective option.

8 Summary of the Report of the Halon Fire Extinguishing Agents Technical Options Committee

8.1 Alternatives to halon fixed systems

New and existing alternatives exist for most halon 1301 total flooding applications. Where replacement of halon 1301 is especially difficult (ground combat vehicle crew bays and certain aviation applications) substantial research and development is underway.

8.2 Alternatives to halon portable fire extinguishers

Although halons provided excellent characteristics as fire extinguishing agents for use in portable fire extinguishers, the use of alternatives for this application has been less problematic than use of alternatives in fixed fire protection systems. In general portable fire extinguishing agents are only applied to actual fires and they can be easily directed at the burning object. As such secondary damage concerns are somewhat less in recognition that fire damage to the object has already occurred. For most applications, multipurpose dry chemical has been the agent of choice, however there are important applications where visibility concerns during firefighting operations and/or ability to permeate are of vital importance.

8.3 Environmental Considerations for Halocarbon Alternative Agents

The primary environmental factors to be considered for these agents are ODP, GWP, and atmospheric lifetime. Comparison of halocarbon replacements with other alternatives should be based on consideration of the environmental impact of each alternative. This should include the impact of production of the agent and hardware, transportation, and storage as well as other factors which determine the total impact of a technology on the environment.

While GWP and atmospheric lifetime are potentially important environmental factors of halon replacement agents, the objective of replacing halons with non-ozone depleting substances is paramount to the goals of the Protocol. Therefore, the use of controlled, non-zero ODP compounds, including HCFCs and HBFCs, as halon replacements is not a wise decision if it can be avoided. As controlled substances, these agents are unlikely to be produced in sufficient quantities that recycled material would be available for long-term support of fire protection systems.

The impact of high atmospheric lifetime, and related high GWP, should be evaluated in the context of the use quantity and emission pattern of chemicals used as halon replacement fire extinguishants. When used only as fire suppressants, there is no likely emission scenario of these compounds which results in measurable environmental impact. However, fire protection represents only one of the potential uses for these substances, and therefore total usage could exceed environmentally acceptable levels. As a result, several governments have already restricted or banned the use of HFCs and PFCs. Such actions may restrict the

commercial availability of these agents, and cause shortfalls in the availability of recycled material necessary for the long-term support of fire protection systems.
Recognizing persuasive environmental concerns, the Halons Technical Options Committee does not endorse the widespread use of HCFCs and HBFCs, or promote the indiscriminate use of PFCs, in preference to other, effective, new or existing technological alternatives for fire protection, which are discussed later in this chapter. The use of any synthetic compound that accumulates in the atmosphere carries some potential risk with regard to atmospheric equilibrium changes, with consequences to long-term availability of the compound and subsequent support for installed fire protection systems.

8.4 Explosion Protection

Halons have been widely used to suppress deflagrations, a class of combustion events characterized by rapid flameball growth and high rates of energy release. Explosions are events resulting in personal injury or destruction of property. Explosion protection is achieved through methods to prevent or mitigate deflagrations. Effective protection of systems and personnel at risk from such events requires operating systems which:

- Create inerted atmospheres, or

- Respond automatically to the incipient event and achieve extinguishing agent concentrations to suppress a deflagration in time scales of the order of 100 milliseconds, and which require agent concentrations much higher than typically employed in total flooding fire suppression applications.

Halons have been specified in industrial, commercial, and military explosion protection applications where either "clean" or people-safe agents were essential. Halon 1301 has the unique property of being able to inert an enclosed space or suppress deflagrations at vapour concentrations which are safe for brief human exposures. Replacement of halon 1301 in such applications presents a significant challenge in fire or explosion protection situations involving human life safety for at present there are no approved alternative agents which have this property. Work is in progress to identify alternative agents which may be approved for these applications. Progress has been made in some applications in designing new explosion protection systems with out specifying halons. Retrofitting of some halon based deflagration suppression systems with environmentally benign agents is occurring though in some cases an unclassified lower ODP clean agent (Halon 1011) is being specified.

8.5 Halon emission reduction strategies

Avoidable halon releases account for greater halon emissions than those needed for fire protection and explosion prevention. Clearly such releases can be minimised, as quantified in Appendix B, if a concerted effort is made by the fire protection community, with support from national governments. In reviewing reduction strategies, the Committee recommends the following:

- Reduce halon usage to essential applications only.
- Discontinue protection system discharge testing using halon as the test gas.
- Discontinue the discharge of portable halon fire extinguishers for training purposes.

- Discontinue the discharging to the atmosphere of portable halon extinguishers and system cylinders during equipment servicing.
- Introduce the use of halon recycling equipment to recover all surplus or reusable material.
- Encourage users of automatic detection/release equipment to take advantage of the latest technology.
- Encourage the application of risk management strategies and good engineering design to take advantage of alternative protection schemes.

8.6 Halon recycling and bank management

The phase out of halon production in the developed countries took place before substitutes and alternatives became available for all critical halon uses. This has been a positive motivation to achieve best use of existing halons and has encouraged the establishment of halon banks and bank management procedures to wisely manage the remaining stocks. Past experience has also shown that 'recycled' halon cannot compete with newly produced material, and thus a prerequisite of any national bank management programme is a commitment to cease production first.

An increasing number of countries, both developed and developing, have initiated or are operating bank management programmes. These programmes take different forms in different countries but, whilst similarities exist, the Halons Technical Options Committee has concluded that no universal template for a bank programme can be produced. This is primarily because the key element of the banking process is the reversal of the original supply/distribution process and this varied from country to country.

Of the bank programmes reviewed, the majority resemble an information clearinghouse. That is, the operators maintain lists of halon users who no longer require halon and those who do but have or will have insufficient stocks to meet their needs. This information is traded between the users who then make the necessary arrangements for 'recycling' of the halon and its sale/purchase. Physical banks that require warehouses and storage tanks are a minority, although it is apparent that large private and military users are forming strategic banks on these lines.

For any banking scheme to work, the fire equipment industry, users and/or government have to agree that a need for a halon bank exists, otherwise there is unlikely to be enough energy, enthusiasm and finance to get a bank started. Governments are also uniquely placed to act as facilitators and to provide a non-commercial forum for discussion and the development of strategies.

Users who obtain 'recycled' halon have to be assured that what they buy is fit for use in fire protection applications. This can best be provided by requiring material to be 'recycled' to a certain agreed standard, or by knowing its provenance. This is particularly import when international trade is involved, as the requirements of the Basel Convention have the potential to be a serious impediment to the transshipment of 'recycled' halons across international boundaries. For this reason, the Halons Technical Options Committee recommends that the Parties to the Montreal Protocol consider:

a) Adopting a decision that international transfers of halons that cannot meet the purity specifications of ISO 7201 or ASTM ES 24-93 should only be allowed if the recipient country has 'recycling' facilities that can process the received halon to either of these standards.

b) Recommending to the Technical Working Group of the Basel Convention that the Basel Convention adopt a decision that, inter alia, halons that are certified to the usable purity specifications ISO 7201 or ASTM ES 24-93 should not be considered hazardous wastes under the Basel Convention.

International cooperation on the movement of 'recycled' halons facilitates access to a bigger market for the sale or purchase of halons, and provides the ability to recharge critical halon systems, such as onboard ships and aircraft, while in a foreign territory. It is therefore important that Parties insure that national regulations that were implemented to restrict imports and exports of newly produced halons do not impede the international trade in 'recycled' halons or their premature destruction.

8.7 Review of industry case studies

The review of these case studies recognised the need to obtain opinions of industry on the strategies developed internally to protect their business interests prior to the cessation of halon production and how they see a future without this media.

The response to the survey request in terms of returns received was excellent. This highlighted the level of responsibility exercised by a large number of industries, by ensuring they have put in place strategies that are achievable in terms of short, medium and long goals to meet the objectives of the Montreal Protocol.

Life without halon can be described in terms of a baby taking its first steps to walk without the aid of its guardian. Some industries have moved very quickly in declaring they can protect their risks scenarios without halons. Consequently they have developed alternative strategies, by way of improving their internal housekeeping practices, and introducing alternative fire protection measures such as improved passive protection, early smoke detection, water and gaseous systems. Other industries are moving a little slower in this process, but the ground rules to progress this route are in place and will continue to gain speed in the foreseeable future.

It is very obvious that there is a current and future need for halons in areas that involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. However, it has also been determined by the results of this industry survey that with well planned fire protection strategies in place it is possible to conserve and make available surplus stocks of halons that can be recycled, banked and made available for areas that fall within the essential use criteria.

8.8 Eliminating halon dependency in developing countries

The elimination of halon dependency is a logical, step by step procedure, that should be implemented in the following order:

1) Build awareness of the problem of ozone depletion
2) Commit to phase out of halons
3) Reduce unnecessary emissions and uses of halons
4) Switch to alternative fire protection methods
5) Develop halon bank management and recycling - eliminate need for newly manufactured halons
6) End halon production

8.9 Essential uses and their needs

The Committee recognises that there are a few fire/explosion risk scenarios for which current fire protection technology cannot provide adequate protection without the use of halons or halon-like replacement extinguishants. These risk scenarios involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. At the same time, the Committee is of the qualified opinion that with proper management, the future needs of the majority of these risk scenarios can be satisfied by redeployment of existing, banked halons until such time, beyond the turn of the century, as the bank expires. The Committee also notes that application specific, replacement extinguishing agents and alternative technologies are now commercially available, and research and development efforts are continuing. In the long term, use of these replacements and alternatives and the others that will be developed in the future, will likely restore the capability to provide fire protection with similar desirable characteristics to those of the present halons for all risk scenarios.

With the possible exception of halon 2402 applications in countries whose economies are in transition, the requirement to produce new halons for critical applications can be avoided by use of halon recycling and banking schemes, and by the early introduction of halon replacements and alternative technologies. Although it may be necessary to reconsider this issue again in the future, the combination of successful bank management, the proper utilisation of lower and zero ODP halon replacements, and the acceptance of alternative technologies, offers the best potential to eliminate the need for a production exemption for essential uses in the foreseeable future.

Establishing a fixed list of risk scenarios that would qualify for a production exemption is neither appropriate or necessary at this time. Continued use of the criteria detailed in this section is the best option at this time and for the foreseeable future. Co-operation at the international level is necessary to ensure that one nation's surplus halon is exported to meet the needs of another nation, rather than destroyed. Parties are encouraged to co-operate with the international fire protection community on bank management, emission reduction and the wise future allocation of the banked halons.

9 Summary of the Report of the Methyl Bromide Technical Options Committee

9.1 Committee Mandate

The Methyl Bromide Technical Options Committee (MBTOC) was established by the Parties to the Protocol to review technical issues concerning methyl bromide, the material listed in Annex E of the Protocol.

MBTOC, and this report in particular, address the technical availability of chemical and non-chemical alternatives for the current uses of methyl bromide, apart from its use as a chemical feedstock. It covers the methodologies to control emissions of methyl bromide into the atmosphere, potential for recovery, reclamation and recycling and the issues of special relevance to Parties operating under Article 5. It also provides an estimate of emissions to the atmosphere from present uses.

The Committee currently consists of 68 members, with representation from 23 countries drawn from a wide range of expertise and interests associated with methyl bromide, including scientists, end users, manufacturers, NGOs, and government representatives from Parties including 8 from Article 5 countries.

9.2 Existing uses of methyl bromide

Methyl bromide is principally used as a fumigant, controlling a wide spectrum of pests, including pathogens, insects and nematodes. It has sufficient phytotoxicity to control many weeds and seeds in soils.

It has features which make it a versatile and convenient material with a wide range of applications. In particular, it is quite penetrative, usually effective at low concentrations and leaves residues which have generally been found acceptable. Its action is usually sufficiently fast and it airs rapidly enough from treated systems to cause relatively little disruption to commerce or crop production.

Methyl bromide is normally supplied and transported as a liquid in pressurised cylinders but at ambient temperature and pressure, the material is a gas. These containers are typically cylinders of about 10 to 200 kg in content, though there is also trade in larger containers and also small pressurised disposable steel cans typically of 0.5 to 1 kg capacity each. Methyl bromide is normally used directly from these cylinders or containers, but may sometimes be transferred to smaller units.

Of the 1992 global sale of methyl bromide of 75,625 tonnes, 3.2% was used as a feedstock for chemical synthesis. It is estimated that the remainder was used for soil treatment (70%), fumigation of durables (16%), fumigation of perishables (8.0%), and fumigation of structures and transportation 2.7%. The proportions for 1991, the base year, are similar to those for 1992. The Committee noted that, in the absence of controls, some developing countries expect to expand uses of methyl bromide substantially. Global consumption, excluding feedstock uses, has increased about 3700 tonnes per year since 1984.

Although methyl bromide is clearly a most useful tool in specific instances, there are a number of issues not related to the ozone depletion, which have led countries to impose restrictions on its use. Concerns include toxicity to humans and associated operator safety and public health, and residues. In some countries, pollution of surface and ground water by methyl bromide and derived bromide ion is also of concern.

9.3 Emissions from methyl bromide use, and their reduction, including recovery

Estimates of the proportion of methyl bromide released into the atmosphere vary widely. Emissions occur inadvertently through leakage and permeation during treatment and intentionally while venting at the end of treatments. The quantity of methyl bromide emitted from a treatment varies on an individual case basis as a result of the use pattern, the condition and nature of the fumigated materials, the degree of seal of the enclosure, and local environmental conditions. Methyl bromide is a reactive material: it is incorrect to equate production with emissions as at least part of methyl bromide applied is converted in use to non-volatile materials.

Under current usage patterns, the proportions of applied methyl bromide emitted eventually to atmosphere globally were estimated by MBTOC to be 30-85%, 48-88%, 85-95% and 90-95% of applied dosage for soil, durables, perishables and structural treatments, respectively. These figures, weighted for proportion of use and particular treatments, correspond to a range of 47-81% overall emission from agricultural and related uses (34,000 - 59,000 tonnes, based on 1992 sales data).

Available containment techniques for decreasing methyl bromide leakage are in limited use worldwide. Lack of adoption is constrained particularly by poor dissemination of information and perceived or real increases in costs and logistical problems. A high degree of containment is a prerequisite for efficient recovery of the used methyl bromide.

Better sealing of enclosures and the use of less permeable sheeting were identified as an immediately applicable, technically proven means of reducing emissions from soil, durable commodity and structural fumigations, with the largest improvement coming from soil fumigation. These measures, combined with longer exposure times, may permit reduced dosage levels while still achieving the required degree of pest control. Many facilities used for fumigating perishables, particularly for quarantine, already have a high standard of gastightness, leading to very low leakage rates (often less than 2% of dosage).

There is active research into the development of recovery and recycling equipment for methyl bromide. A few special examples of recovery equipment are in use and it is anticipated that prototype systems capable of recycling recaptured gas for some use areas will be evaluated by the end of 1995. Most development work is directed at recovery from enclosures used for structure or commodity fumigation (about 24% of global production). Some preliminary work on recovery for soil fumigation is in progress.

It is unlikely that significant demand from developing countries can be met with recycled material. There is, however, potential for some recycling in some specialised applications, including in Article 5 countries, when commodities, notably perishables, are treated in gastight chambers.

Most of the potential recovery and recycling systems are complex and may be expensive to install compared with the cost of the fumigation facility itself. Some systems would have high running costs associated with energy requirements. Many would require a level of technical competence to operate that would not normally be found at many fumigation facilities.

If recovery is to be recognised as an acceptable method of reducing methyl bromide emissions to the atmosphere, it will be necessary to set specifications on aspects of fumigation, such as equipment efficiency and tolerable levels for emission.

9.4 Alternatives to methyl bromide

There is no single alternative to methyl bromide in all of its wide range of uses. However, technically, alternatives do already exist for a number of current applications.

A number of potential alternative chemicals have been identified. They include fumigants and non-fumigants. However, the environment and health considerations, which may limit the use of any pesticide, including methyl bromide, need to be taken into account when selecting alternatives.

Furthermore, it is very likely that regulatory restrictions on use of agrochemicals will increase, resulting in higher costs of use and increasing inconvenience. Additionally, costs of achieving full commercial registration of unregistered materials are high, and the process is slow.

It was noted that there are specific constraints on rapid implementation of some alternatives associated with the time taken to gain registration and regulatory acceptance of some procedures. The problem is particularly acute in some cases relating to treatment of exports to meet quarantine standards where extensive trials and protracted bilateral negotiations may be required.

Many of the alternatives identified by MBTOC were of the 'not-in-kind' type. In a number of cases a rational combination of procedures, including non-chemical measures, can be used to avoid creating the circumstances where methyl bromide is currently regarded as irreplaceable. This approach, known as Integrated Pest Management (IPM), utilises pest monitoring techniques, establishment of pest injury thresholds, and a mix of tactics selected to prevent or manage pest problems. Emphasis is placed on producing a marketable crop using safe, environmentally sound and cost-effective procedures. Chemical intervention, at present possibly including use of methyl bromide, is employed only on the basis of need rather than by routine. The ability to design IPM depends on a thorough knowledge of the pest or disease complex to be controlled.

In general, the effect on production and profitability will vary widely and may lead to increases, or decreases, depending on local circumstances. In the only instance of methyl bromide phaseout for soil fumigation throughout a country (the Netherlands) it is reported that adoption of some alternatives have increased yields in specific crops.

MBTOC estimates that by using known technology it is technically possible for Parties operating under Article 2 to significantly reduce usage of methyl bromide. Estimates of the magnitude of the reduction and its time scale varied widely amongst MBTOC members. Opinions ranged from a reduction of 50% feasible by 1998, to decreases of only a few percent by 2001. Reductions should be achievable through a combination of implementing alternatives and use of better containment technology, together with longer exposure times and lower dosages for methyl bromide treatment, particularly in soil fumigation. Achievement of such reductions may entail use of some alternatives which may have potential to cause adverse environmental and health effects. Some alternatives, notably those leading to residues in products, while technically effective, may not be acceptable to regulatory authorities, markets or end users.

MBTOC did not identify a technically feasible alternative, either currently available or at an advanced stage of development, for less than 10% of 1991 methyl bromide use. These include control of some soilborne viruses and other pathogens and some quarantine procedures.

MBTOC assumed that the most energy intensive alternative to methyl bromide was use of steam heating for soil treatment. The indirect Global Warming Potential of methyl bromide, in terms of CO_2 produced, with energy required supplied electrically, was 20 kg CO_2 per tonne for synthesis and vaporisation. Using equivalent energy sources, steaming at 4-7 m^3 per m2 and methyl bromide at 25-100 g per m^2 were equivalent to 21-37 and 5-20 kg CO_2 per m2. The atmospheric lifetimes of all gaseous potential alternatives to methyl bromide were too short to give appreciable direct GWP.

9.5 Alternatives on a sector basis

9.5.1 Soils

On a global basis, the largest single use of methyl bromide is as a soil fumigant (70% of global production). It is used as a pre-plant soil fumigant to maintain or enhance crop productivity in locations where a broad complex of soilborne pests, including diseases, limit economic production of certain crops, and particularly where they are repeatedly grown on the same land. Methyl bromide has been successfully used under a wide variety of cropping systems. The major current categories of use include some nursery crops, vegetables, fruits, ornamentals and tobacco.

Soil fumigation with methyl bromide has been successfully replaced in diverse areas by methods and techniques that have been available for many years, by adapting or modifying them to suit local requirements. None of the specific alternative methods discussed, except steam, when used alone, have the broad spectrum of activity, efficacy or consistency of methyl bromide. For some situations there may not be existing alternatives for methyl bromide. The development of a comparable agricultural system without the use of methyl bromide, in many cases, may require the integration of multiple alternative techniques (IPM). A commitment to research and technology transfer will be required to achieve a similar spectrum of efficacy and reliability, and adoption by growers.

An IPM approach to managing pests and diseases will be needed in order to avoid future environmental problems associated with soilborne pest control. Each individual tactic in an IPM strategy may have constraints, but the package of approaches can often be tailored to specific sites and situations to provide effective pest management. In this context, constraints should be viewed as indicating research gaps. Research to overcome these constraints needs to focus not only on biophysical systems, but also socio-economic and political parameters, and generation of registration data.

A number of non-chemical alternatives are currently in use and other potential alternatives are under investigation. These are not equally effective for all pests, cropping systems or locations and may have a narrow spectrum of activity. Non-chemical alternatives include:

- Cultural practices such as crop rotation, planting time, artificial plant growth substrates, deep ploughing, flooding/water management, fallowing, cover crops, living mulches, fertilization/plant nutrition, and plant breeding and grafting.
- Biological control and organic amendments

- Physical methods such as soil solarization, steam treatments, superheated or hot water treatments and wavelength-selective plastic mulches.

Non-chemical alternatives generally do not require extensive regulatory approval.

There are a number of available and potential replacement fumigants, including methylisothiocyanate (MITC), compounds which generate MITC, and halogenated hydrocarbons. Mixtures of soil fumigants may provide a spectrum of control approaching that of methyl bromide. These combination products may represent the most efficacious short term alternatives to methyl bromide in certain situations, provided they are acceptable to regulatory agencies.

Control of individual soilborne pests and diseases approximating that of methyl bromide may be achieved in some cases through the use of combinations of non-fumigant materials (e.g. nematicides, fungicides, herbicides and insecticides).

There are additional chemicals which would require further research to determine their potential as alternatives for methyl bromide. Some were previously used with varying degrees of success (e.g. anhydrous ammonia, formaldehyde, carbon bisulphide, inorganic azides). Renewed interest and research may lead to re-establishment of some of these pesticides.

9.5.2 Durables

Durables include dry agricultural and forestry products, such as cereal grains, dried fruits and nuts, timber and artifacts. Approximately 16% of the annual global production of methyl bromide is used for disinfestation of durable commodities. Generally, methyl bromide is not widely used on durables but a few economically important industries have a tradition of use of methyl bromide fumigation as their principal means of pest control. These include the dried fruit and nut industry, some major importers and exporters of cereal grains, and export trade in un-sawn timber. Methyl bromide is particularly useful where a rapid treatment is needed, such as at import or prior to shipment, and for quarantine purposes. It is effective down to low commodity temperatures (5°C).

There are potential or existing alternatives for most uses of methyl bromide on durable commodities. However, there is no general in-kind replacement. All alternatives will require some changes in practice. Of the alternatives, only phosphine is extensively used, principally for cereals and legumes. Insect resistance to phosphine is an emerging problem, particularly in developing countries, but resistant pests can, at present, be controlled using currently used phosphine-based technology.

Some alternatives are already in industrial use for some classes of durable. Those identified include other fumigants, controlled and modified atmospheres, contact insecticides, physical methods and biological control methods.. Many are limited in particular circumstances by speed of action, regulatory constraints, temperature, consumer acceptance, and lack of research data.

9.5.3 Perishables

Perishable commodities include fresh fruits and vegetables, cut flowers, ornamental plants, fresh root crops and bulbs. Methyl bromide fumigation is the predominant treatment when disinfestation is required for perishable commodities, using about 8% of global methyl bromide production, with about half of that for disinfestation of fruit for quarantine purposes. A minor quantity of methyl bromide, less than 0.2% of global use, is used to help prevent the spread of pests within countries.

Alternative treatments to methyl bromide include pest-free zones, inspection, physical removal, the systems approach; and disinfestation based on chemical treatments, cold-storage, heat, controlled and modified atmospheres, irradiation and a combination of these treatments. Although these are approved for disinfestation of specific commodities, very few are in use relative to the number of different commodities treated with methyl bromide. Their widespread application is limited in some cases by their commodity and pest specificity. There are also very few examples of alternative treatments developed for commodities routinely treated with methyl bromide because few people recognised the need to develop them until now.

For each alternative, MBTOC identified a number of specific approvals in various countries. For example, heat treatments are approved for 14 applications, chemical fumigants for 12, cold treatments for nine, pest-free zones for four, and irradiation for two. Currently, there are no existing alternatives, meeting quarantine standards, for five groups of economically important exports: apples and pears infested with codling moth; stonefruit infested with codling moth; grapes potentially infested with a certain mite (from Chile to the USA); berryfruit infested with various insects; and certain root vegetables where soil is not removed.

Some promising alternatives require further research to determine their suitability for control of pests in specific commodities. MBTOC identified twelve potential alternative treatments.

MBTOC noted that there are constraints on use of chemical treatments for disinfestation of perishables and that they have very limited application. They are difficult to apply, have a narrow pest spectrum of activity, can damage many commodities, and are not approved for use in some countries. Many consumers have indicated preference for foods with less or without chemical residues, provided they are of good quality and value.

Perishable commodities absorb relatively little methyl bromide, leaving 85-95% available for recovery. Many perishable commodity fumigations are carried out using well-sealed solid-wall facilities, that restrict leakage. There is thus opportunity for efficient recovering and recycling. Where alternatives are not feasible for quarantine treatments, minimising methyl bromide released using recapture technology could be used to maintain national and international trade in perishables.

9.5.4 Structures and transportation vehicles

Treatment of structures and transport vehicles uses about 2.7% of global methyl bromide production.

Fumigation is used as a structural pest management technique on either an entire structure or a significant portion of a structure. It is utilized whenever the infestation is so widespread that localized treatments may result in reinfestation or when the infestation is within the walls or other inaccessible areas.

Structures that are fumigated are classified as food production and storage facilities (mills, food processing, distribution warehouses); non-food facilities (dwellings, museums), and transport vehicles (trucks, ships, aircraft, railcars).

Pest management in these facilities is best achieved through IPM procedures. These may include periodic full site treatments. Reduction or elimination of the use of methyl bromide can be accomplished with IPM programs in some situations, including some full site treatments. Structural IPM relies on good construction and maintenance with modification, where required, to remove pest harbourages, and sanitation to remove pests and their food sources. Pest detection serves as a quality assurance for the pest management program, and indicator of need for treatment.

There are significant opportunities to reduce methyl bromide dosage through better containment and monitoring, and combining methyl bromide with carbon dioxide.

Presently, there is no single substitute fumigant for methyl bromide for all treatments of structures against pest infestation. Phosphine and hydrogen cyanide are alternative fumigants in some situations, including full site treatments. Sulphuryl fluoride is used as a direct substitute for methyl bromide to eradicate wood destroying insects in some countries. Non-fumigant pesticides and non-chemical methods are also being used as local treatments. Heat treatment is probably the most useful non-chemical fullsite technique. Other alternative pest management strategies incorporate the use of non-fumigant pesticides and non-chemical procedures.

Transport vehicles pose particularly difficult pest management problems because they often contain sensitive equipment, innumerable harbourages and it is economically difficult to keep them out of operation for more than a brief period. Furthermore, methyl bromide is the only fumigant currently allowed for quarantine treatments on ships in many countries. Presently there are no established alternatives to methyl bromide for rapid rodent and insect elimination aboard aircraft.

9.6 Concerns relating to Article 5 countries

Developing countries currently use about 18% of methyl bromide produced globally for agricultural and related uses. The main uses are for soil fumigation (about 70% of total) and disinfestation of durables (about 20%).

Soil fumigation is mainly carried out in Article 5 countries for pest and disease control in the production of certain high value cash crops (e.g., tobacco, cut flowers, strawberries, vegetables). It is used particularly for fumigation of nursery and seed beds. Methyl bromide is not used during production of staple foodstuffs. Where used on durables, the main application is the protection of local stocks of food grains and for disinfestation of imported and exported cereal grains. Some perishables, important to particular economies, are fumigated on export to developed countries.

Alternatives to methyl bromide in developing countries and potential constraints on their use are the same as in developed countries, but some chemical treatments, not permitted in some developed countries, may still be acceptable. Application is generally further constrained by the social conditions, level of infrastructure and other conditions typical of many Article 5 countries.

At present there is no single in-kind alternative for all uses of methyl bromide in developing countries. For some quarantine applications (e.g. certain berryfruit infested with thrips or aphids, certain unwashed root vegetables infested with soil pests) there are currently no technically feasible alternatives.

It may be possible to use alternative treatments and/or production methods, including IPM strategies, to substitute for most of the pest control uses of methyl bromide. However, the varied and special conditions in Article 5 countries require that the alternatives be appropriately adapted to the climatic conditions, particular cropping techniques, resource availability and specific target pests. Different alternatives will have to be used for different crops, commodities and situations. This is likely to involve significant effort to select appropriate alternatives, adaptive research, field testing, technology transfer, user education, institutional capacity building and training, among other factors. It is critical that those Article 5 countries which utilize methyl bromide receive technical and financial assistance to introduce or adapt alternative materials and methods to manage the pests currently controlled by methyl bromide.

The Committee noted that the specified incremental costs eligible for funding under the Multilateral Fund and items on the indicative list may need revision in order to accommodate the special needs associated with methyl bromide, if phaseout is considered.

Potential trade restrictions relating to methyl bromide use are of great concern to those Article 5 countries dependent on certain exports now produced with the aid of methyl bromide. Such restrictions, which could be applied by developed, importing countries and regions, as a result of their own or international restrictions on methyl bromide, are seen as an issue of substantial importance. They could nullify the effect of any grace period.

10 Summary of the Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee

10.1 Refrigerant data

This section considers the properties of refrigerants for use in the vapour compression cycle. Namely, the vast majority of present equipment utilises the vapour compression cycle because of its simplicity and good efficiency. The dominance of this cycle is not likely to change simply due to the need to replace the chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs); it will prevail even after the phaseout of the latter substances.

The ideal refrigerant will satisfy a set of criteria, including chemical stability, non-flammability, and low toxicity, the need for favourable thermophysical properties, and other, more practical, considerations such as materials compatibility. Although many types of fluids have been used as refrigerants in the past, the halocarbons dominate today because their unique combination of properties proved to best satisfy these sometimes conflicting requirements. Experience with the CFCs has shown, however, that substances possessing the chemical stability desirable in a refrigeration system can, when emitted, accumulate in the atmosphere and cause unacceptable environmental harm.

Because of the success of the CFC refrigerants, most of the efforts to develop replacement refrigerants have focused on a set of hydrogen containing, but otherwise similar, compounds. At present, hydrocarbons and other simple inorganic compounds (the so called natural refrigerants) are receiving increased interest. This choice is confirmed by theoretical studies which indicate that simple molecules of relatively low molecular mass and with normal boiling points similar to present working fluids would be excellent refrigerants. These fluids include HFCs -134a, -152a, -125, -32, -143a and -23, and HCFCs -22, -123, -124, and -142b. These fluids are the popular choices for the immediate replacement of the CFCs; some of these fluids are also acceptable long term replacements. Mixtures of these fluids are also good candidates.

The light hydrocarbons such as propane, butane, and isobutane will likely see increased use; since they have excellent environmental and thermophysical properties. However, they are flammable, and must only be used in systems which operate safely with flammables. Ammonia, a refrigerant that currently dominates certain applications, is being considered for a broader range of uses; it is, however, flammable and toxic. Water, carbon dioxide, and air may also be used as refrigerants, but require different types of equipment. Additional classes of fluids, such as the fluorinated propanes and fluorinated ethers, show some promise as refrigerants; such fluids, however, are in the very early stages of development and would not be available in large quantities for many years.

Data of a variety of types are required to evaluate a potential alternative refrigerant. The thermophysical (i.e., thermodynamic and transport) properties of a fluid determine its energy efficiency and heating or cooling capacity in equipment and are essential for equipment design. Properties related to health and safety (toxicity and flammability) can determine whether a fluid is suitable for a particular application. Data on materials compatibility are required to design reliable equipment. The environmental characteristics of ozone depletion potential (ODP), atmospheric life, and the greenhouse warming potential (GWP) taken together with the coefficient of performance of the refrigeration system and emissions due to leakage, servicing, and disposal (that is, the total equivalent warming impact, or TEWI, concept) will determine whether a fluid should be considered an acceptable alternative to the CFCs.

Only simple parameters such as normal boiling point and molecular structure are needed to conduct a coarse screening among many candidates, while widespread commercial use requires extensive, accurate data of all types. In section 2 of the Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Committee, the needed data are described and categorised, and the available data are summarised for the leading candidate refrigerants.

The greatest impediment, however, to selecting, developing, and commercialising alternative refrigerants is the uncertainty regarding the relative weight to be given to ozone depletion potential, global warming potential, energy efficiency, and safety factors such as flammability.

10.2 Domestic refrigeration

Approximately 64 million refrigerator-freezers are manufactured worldwide each year. Hundreds of millions are currently in use. The majority of these units employ the vapour compression cycle with CFC-12 as the working fluid, typically containing between 20 and 600 grams of CFC-12 refrigerant, globally. The efficient use of energy by refrigerator-freezers has assumed more importance due to the emphasis on reducing global warming.

Advanced vapour compression cycles employing separate evaporators in the fresh food and freezer compartments are receiving significant research attention. A circuit employing zeotropic mixtures and configured in the manner prescribed by Lorenz and Meutzner has been predicted to yield efficiency gains up to 26%; gains of 15% have been experimentally realised to date. Several patents have been issued on alternative two-evaporator configurations for use with constant boiling refrigerants. Efficiency gains of the order of 20% to 30% are predicted. Continuous compressor capacity modulation is another modification estimated to provide efficiency improvement of the order of 10% to 20%.

As new equipment alternatives to CFC-12, candidates have been assessed versus criteria encompassing environmental acceptability, safety, reliability, efficiency, process capability, availability and cost. Regional differences in refrigerant choice are driven by variations in consumer lifestyles and preference, government regulations, and industry offerings. Two refrigerants dominate current implementation efforts throughout the world. HFC-134a is the preferred alternative in the Americas, Asia/Oceania and selective applications in every region of the world. It is nonflammable and has zero ozone depletion potential. HC-600a is the alternate being widely adopted in Europe. It is flammable, has zero ozone depletion potential and a greenhouse warming potential approaching zero. Other alternative refrigerants receiving regional or niche product consideration are: HFC-152a, HC-290/HC-600a blends and the R-401A/B and R-409A blends (HCFC/HFC ternary blend).

Product configuration is a critical parameter for assessing risks. The safety aspects of each unique product configuration must be rigorously assessed. Substantive product redesign, possibly including new concept introductions, will be required to alleviate safety concerns with the use of flammable refrigerants for no-frost refrigerator-freezers.

Proof of concept demonstration with resonating piston, Stirling coolers indicate efficiencies comparable to current refrigerator-freezers. High entry investment, no long term reliability information and no demonstrated efficiency advantages over conventional systems constrain interest. Thermoacoustic refrigeration, sonic compression and linear compressor technology are promising new technologies. Broadened general insight is necessary for informed decisions regarding applicability. Absorption cycle refrigeration is not expected to penetrate beyond its historic niche segment.

Manufacturers will continue to service existing refrigerator-freezers with CFC-12 as long as it is available and less expensive than other retrofit candidates. Since retrofit options are limited, the HCFC/HFC ternary blends could achieve significant usage. HC-290/HC-600a hydrocarbon blends would function well, but must be carefully assessed for application for each unique configuration from a safety perspective. Appliances that have not been designed for their use should not apply flammables in servicing if not the appropriate safety measures have been taken. HFC-134a is not a practical alternate for retrofitting. Part of the CFC-12 service demand will be satisfied by recovered CFC-12 during field service or by recovery at disposal and reclamation to acceptable purity standards.

CFC-12 usage for domestic refrigerator/freezers was 9,100 metric tonnes in 1990, 75% of this amount consumed in the developed countries. It is estimated that 70% of the production units will be converted to HFC-134a, and 30% will be converted to isobutane. Further use of isobutane will be mainly determined by the fact whether - compared to other non ozone depleting options- high energy efficiencies can be achieved. HCFC usage is not expected to exceed 3% of total refrigerant demand. Regarding transition timings, it is currently estimated that 85% of the developing (Article 5(1)) countries new unit production and 15% of developed countries new unit production will be using CFC-12 in 1995. By 1997, 70% of Article 5(1) countries' new production will still be using CFC-12 while other countries will be CFC free. Article 5(1) countries new production usage is expected to be down to 10% by 2000 and CFC free by 2005.

Categorising Article 5(1) countries by their apparent strategic intents toward domestic refrigerator-freezers - i.e., in finished product import only, finished product manufacture for domestic use and/or export, and/or hermetic component manufacture for domestic use and/or export- provides insight toward their technology and timings needs as well as probable technology access options. Significant product or component import/export activities with developed countries will require accelerated CFC phaseout timing, consistent with the needs of the trading partner(s). Service, retrofit and reclamation technologies are viewed to be particularly acute needs for Article 5(1) countries.

Considering processing technology considerations, the compatibility of materials, chemicals and components processes must be understood to maintain quality and reliability standards. Heightened discipline for manufacturing cleanliness and process control are essential for the successful application of HFC-134a. Required purity levels for hydrocarbon refrigerants are still being debated.

10.3 Commercial refrigeration

Commercial refrigeration encompasses equipment and systems ranging from a fraction of one kW to many hundreds of kWs extending across the food industry applications to hospitals, hotels, corner shops through to engineering quality control applications.

CFC consumption, primarily R-12 and R-502, has been reduced in the last 3 years in most industrialised nations primarily by switching over to HCFC-22 and HCFC-22 containing blends and to a much lesser extent to HFC blends. There is still a reluctance to make changes until it is seen that there is a freedom from service related problems and that reliable and sound engineering procedures exist, thereby minimising risks and costs.

Areas of uncertainty do exist especially with the small unitary equipment utilising hermetic compressors. This is particularly the case where high temperature or tropical operating conditions exist and where the scope for retrofitting is limited.

The phaseout of CFCs by 1996 appears feasible and more experience with the use of HFCs is needed to prepare for the eventual phaseout of HCFCs within the allotted time scale. For new equipment the move out of CFCs has generally been more pronounced, especially to HCFCs, however the subsequent use of HFCs for many operators is dependent on equipment manufacturers development and testing to produce a price competitive product and reliable procedures.

Advice for those facing the decision to move from CFCs to HCFCs and/or directly to HFCs, is available from various sources and free exchange of such information should be encouraged to accelerate the conversion progress.

Technology transfer to developing countries, particularly in respect to the sharing of practical experience identified in this section could be expanded by communicating successful retrofit and new applications case histories, to facilitate the phaseout of CFCs.

Of equal importance is the international acceptance of HFCs as the logical successor of CFC and HCFC for the majority of commercial applications, notwithstanding the progress in many areas to investigate the use of non-fluorocarbon and not in kind alternatives.

Reduction of leakage, recovery of refrigerants coupled with a general reduction from service/breakdown related activities continue to improve in commercial refrigeration. This is of considerable significance when applying the TEWI concept to the selection of refrigerants due to the contribution of high leakage rates on the direct effect of global warming. With reduced emissions currently evaluated HFCs are most viable when used at higher system efficiency levels, making the TEWI favourable.

Future trends include designs with reduced refrigerant charge, an increase in self-contained (unitary) display cases, more efficient compressors, improved electronics for diagnostics and efficiency improvements plus encouraging moves to secondary refrigerants for some applications.

The use of primary refrigerants such as ammonia and HFCs require experienced, skilled engineers. To provide the training to produce engineers with such skills presents a major challenge which must be addressed, if progress is to be maintained.

10.4 Cold storage and food processing

Cold storage and food processing is one of society's most important applications of modern refrigeration techniques. Cold storage and food processing include a wide variety of applications especially if cold storage is not restricted to the simple storage of foods and indeed when food processing is extended to cover such fields as the freezing, dairy and brewing industries.

Foods such as dairy products, fish, meat, fruit and vegetables are stored and distributed in huge quantities in a chilled condition. Frozen foods are generally stored in the temperature range -18 to -30°C. Some fish products intended to be eaten raw are stored at temperatures even lower than -50°C. Food processing, which includes freezing, may take place at air and refrigeration temperatures down to -40°C and lower.

The industrial cold storage and food processing sector is a vital element in the safety and health of the world population. The preservation of the world food supply is vital to stability and economic growth throughout the world. The world frozen food production in 1992 was approximately 27.5 million metric tonnes but represents only a small part of the total food volume preserved by refrigeration. As the transportation and distribution infrastructure of the developing countries improves, significant increases in the need for cold storage is likely to occur. This will probably follow the same patterns as in the developed countries and will eventually stabilize where the chilled food is about 10 to 12 times that of the frozen products.

Since the 1991 assessment the world has seen a return to the use of ammonia in the large scale chilling, freezing and cold storage systems. Simultaneously, strenuous efforts have been made to reduce the size of the ammonia charge in large systems by using plate-type heat exchangers and secondary refrigerants or by using low charge, low pressure receiver ammonia systems which avoids using circulation pumps that require a large refrigerant volume.

In countries where there are severe restrictions on using ammonia, other refrigerants are being examined as replacements. One of the past alternatives to ammonia has been HCFC-22. However, because it is slated for phaseout, HCFC-22 will eventually become unavailable requiring the current systems to either be replaced or retrofitted with other alternatives. One of the current replacements for CFC-12 is HFC-134a. However, R-134a has only limited use as a replacement in this application because R-12 is not widely used in cold storage and food processing. Another widely used refrigerant in this application is R-502 which has a series of alternatives on the market in the form of blends. However, the "blends" that replicate the properties of R-502 are slightly more expensive, many contain HCFC-22, and many have been criticised for their global warming potential, which is still well below R-502.

While other refrigerants such as hydrocarbons, carbon dioxide and water may have a role in cold storage and food processing they are currently not expected to become a significant portion of the refrigerants being used in these applications.

Currently, there are no alternative technologies available that will play an important role in the replacement of the existing equipment used in this sector.

Retrofits in this sector while possible are difficult to actually implement. Generally speaking ammonia can not be used as a direct substitute in equipment not specifically designed for its use. The current halocarbons being extensively used (HCFC-22 and R-502) do have suitable direct "drop-in" alternatives, however, may require redesigned systems for truly effective, efficient operation. These factors tend to mitigate against retrofits and move the users toward other approaches (such as extending the life of the system by recovery and recycle of refrigerant, stockpiling, and refrigerant conservation\leak prevention activities). Currently, replacement systems must be specially designed and produced for the specific situation.

Currently, ammonia is the most readily available, environmentally acceptable refrigerant for food processing, chilling, freezing and cold storage. However, a major problem is finding ways of using ammonia acceptably in countries that have severe restrictions on its use based on safety concerns and legal liability precedents. A reasonable approach to general acceptance of ammonia would seem to be system re-designs to reduce refrigerant charge, produce automatic oil return and allow operation of unoccupied engine-rooms. Significant progress has already been achieved in this area but general acceptance of ammonia in the USA and Japan may continue to be slow. The old-fashioned style of large charge, pump circulated ammonia systems will always play a role in industrial size for large Food Processors and Cold Storage. However, non-pump circulation overfeed systems will play an increasing role. Indirect systems with low charge ammonia circuits (50 - 100 kg) placed outside buildings and on the roofs of buildings will also become more common. These small charges can be easily handled in the event of a leak and ammonia, one of the very few refrigerants lighter than air, will disperse upwards when released.

10.5 Industrial refrigeration

Industrial refrigeration covers a wide range of uses and operating conditions, primarily within the chemical, petrochemical and pharmaceutical industries, the oil and gas industry, the metallurgical industry, industrial ice making and sports and leisure facilities. Most systems are situated in industrial areas without public access. Therefore, toxic and flammable refrigerants, like ammonia and hydrocarbons, can often be safely used.

In developed countries CFCs are already virtually phased out in new industrial systems, only some 2500-3000 tonnes/year is required for service purposes. This demand will decline gradually, and is expected to die completely out in 10-15 years. Many Article 5 countries have decided to accelerate CFC phaseout, and CFC consumption is expected not to increase above current level of 500-1000 tonnes/year. After the year 2000, CFC use is likely to fall off also in these countries.

Annual HCFC consumption for industrial purposes in the developed countries is believed to be in the order of 13000 tonnes/year, or five times current use of CFCs, while Article 5 countries are expected to consume equally much HCFCs and CFCs. HFC consumption worldwide is currently believed to be less than 1000 tonnes per year.

The trend with respect to selection of replacement fluids for the CFCs varies markedly. In response to the outlook for more stringent HCFC regulations in Europe, many European countries have turned to ammonia, which has gained up to 70-80% market share for new installations.

In the United States and Japan, HCFC-22 has been the most common CFC alternative so far, and will most probably continue to be the first choice. Ammonia is expected to gain shares also in these markets, but less than the hydrofluorocarbons (HFCs), which are expected to remain significant in the long term. While technology with HFC-134a is considered to be mature for new industrial applications, HFC blends may still require a certain period to reach full maturity.

Technically, ammonia can be used for most industrial applications (ref. current development in some European countries), and it should always be considered a candidate; however it may imply that national regulations may need to be updated to permit its use. New technological developments have enabled strong reductions in system charge, and furthermore, made ammonia technology cost competitive in more applications.

Existing CFC systems, containing some 30,000 tonnes of chemicals, represent the greatest challenge in the short term. In principle, most installations can be retrofitted to use a non-regulated fluid. On the other hand, systems using BFC-13 (which is, in fact, halon-1301) make an important exception, since no fluid with similar properties exists.

Technology to retrofit CFC-12 industrial systems to use HFC-134a is fully mature in 1994, while change-over from R-502 to an HFC blend, e.g. HFC-404A, will be available by the mid 1990s. Proven HFC blend technology may be available towards the end of the decade. Retrofit to use ammonia may be feasible in some cases.

Restricted availability of qualified service engineers to do the retrofit work may become a serious limiting factor in the short term.

Reduced emissions and recovery and reuse will play an important role in the short term to keep existing systems in operation. Nonetheless, shortage of refrigerant may force premature decommissioning. Possible reductions in energy consumption and improved flexibility with modern technology may reduce the cost effects for the end users.

A "most likely" scenario regarding the state of current stock of systems by the year 2000 implies an even distribution among retirement (natural and premature), retrofit and operation on recycled/stockpiled fluid.

HCFCs will be required to meet refrigerant demand in an interim period, since neither technology nor supply of chlorine free alternatives will be available in the near term. It is believed that up to 10 years may be required to enable industrial refrigeration to cope completely without HCFCs.

In the industrialised countries, HCFC consumption is likely to fall slightly off during the rest of the nineties, while a strong acceleration in the reduction is foreseen thereafter. By 2005, HCFC demand is believed to be only half of current consumption. A certain portion will be covered by reuse.

During the next decade, HCFC consumption in Article 5 countries is expected to nearly double, but will still be comparatively low by 2005 (1500-2000 tonnes/year). To minimise costs and ensure that best technology is identified for all applications, HCFCs should be available 5-10 years longer in Article 5 countries compared to developed countries.

HFCs will gain increased importance both for retrofit and new installations towards the year 2000. Consumption figures world wide will most probably exceed those of HCFCs by 2005 or shortly thereafter.

Change-over to ammonia will normally imply improved energy efficiency, while reference cycle efficiency will be lower with some of the new fluids. This may be compensated for by system optimisation and computer based regulation and control. On average, and in a first instance, energy consumption is expected to remain practically unchanged.

10.6 Air conditioning & heat pumps (air cooled systems)

The product categories included within the unitary (air cooled) product group are ducted and non-ducted split systems, single package room air conditioners and commercial single and multi-zone packaged air conditioners (the term air conditioners is assumed to include heat pumps). Nearly all of these products utilize HCFC-22 as the refrigerant. Globally, unitary (air cooled) air conditioners account for approximately 32% of the total world consumption of HCFC-22.

The estimated quantity of refrigerant contained in the installed population (approximately 214,000,000 units) of these products is estimated to be 364,000 metric-tonnes. The 1994 HCFC-22 demand to manufacture and service this category of products is estimated to be 85,000 metric-tonnes.

Several promising HCFC-22 alternatives are currently under investigation. These alternatives include hydrofluorocarbons (HFCs), hydrocarbons (HCs) and a few naturally occurring compounds (ammonia). The majority of the HCFC-22 replacement candidates has zero ozone depletion potential. At this time the most promising HCFC-22 replacement candidates for this class of products are the HFC compounds. The HFC compounds have been extensively evaluated through the ARI AREP program and through many other research programs within the international community. The results of this research indicate that several HFC compounds could be suitable replacements for HCFC-22.

The HFC compounds have been criticised because of their direct global warming potentials. However, it is important to consider both the direct (portion caused by the refrigerant) and indirect (portion resulting from the energy required to operate the appliance during its lifetime) of the global warming impact when comparing different refrigerant options. For unitary equipment, the indirect effect can represent over 90 percent of the total global warming impact. The Total Equivalent Warming Impact (TEWI) is a factor which combines these two terms for a refrigerant. The TEWI values for the HFC refrigerants are equal or lower than for most of the other alternative refrigerants.

Equipment using alternative refrigerants is expected to be available in the 1996-1998 time period. Widespread availability is not expected to occur until 2000-2005.

An analysis of the demand for HCFC-22 was made assuming three different conversion rates: pessimistic, optimistic and most likely. The peak demand for HCFC-22 for this category of products was calculated to be approximately 95,000 metric tonnes with the peak occurring between 1998 and 2005. The demand for new HCFC-22 for these products should decline to between 10,000-30,000 metric-tonnes by the year 2015 versus the 1994 demand of 85,000 metric-tonnes. This analysis used to generate this estimate assumed a fairly aggressive recovery/recycling effort on the part of the world community. Should the world community fail to adopt aggressive refrigerant recycling programs shortages of HCFC-22 could occur during the next decade.

The primary technical concerns of the developing countries are: adequate supplies of HCFCs to service existing equipment and equipment manufactured before the HCFC phaseout date dictated by the Protocol, adequate supplies of alternative substances and technologies and concerns over the cost and safety of the alternative refrigerants and technologies.

Data on the cost of these refrigerants and the redesigned systems in which they would be applied are just now being evaluated by researchers. Some of these technologies are ideally suited to developing countries. Technologies which are complex and in their early stages of development will probably be too costly or complex for consideration by developing countries.

Equipment and operating costs are real barriers to the entry of larger residential and commercial unitary products into a country. If the benefits of air conditioning are to be experienced on a wide scale, incremental costs must be kept to a minimum. It is therefore important to develop alternative refrigerants and technologies which are both environmentally safe and cost effective. Technologies which are environmentally safe but also expensive and complex to implement would be a detriment to rapid conversion in developing countries.

10.7 Air conditioning (water chillers)

HCFC-22 has been used in small chillers employing positive displacement compressors and in very large chillers employing centrifugal compressors. CFC-11 and CFC-12 have been used in large centrifugal chillers. Due to the CFC phaseout, CFC-11 and -12 have been essentially replaced in new equipment production by HCFC-123 and HFC-134a, respectively. To date, no alternate has displaced HCFC-22 in the small and very large chillers.

HFC-134a is sometimes used in positive displacement water chillers. HCFC-123 is an energy efficient refrigerant that meets the basic design requirements for low pressure centrifugal compressors. This accounts for its use in centrifugal chillers in the 350 to 5000 kW range. HCFC-22 is used in the largest centrifugal chillers, from 1000 kW up to 35000 kW.

CFC-114 has been used in some centrifugal chillers, particularly those in naval vessels. These applications are expected to be converted to HCFC-124 or HFC-236fa, or replaced by HFC-134a chillers.

New equipment and refrigerants

Positive Displacement Compressor Chillers

The planned HCFC-22 phaseout has led to intense activity to find and characterize appropriate alternates. The refrigerants which appear to be most promising in terms of their ability to satisfy the performance and safety criteria are the blends of the HFCs. Azeotropic mixtures are under consideration as HCFC-22 replacements because they tend to act as single component refrigerant, i.e. the vapour and liquid composition at a given temperature and pressure is constant. However, based on a very extensive search of alternatives, it is clear that there is no drop-in replacement for HCFC-22 in chillers with flooded evaporators today, nor is one foreseen. One implication of this is that any further acceleration of the phaseout of HCFC-22 would have serious consequences for the stock of HCFC-22 chillers in service at the time of the phaseout.

HFC-134a is being used in positive displacement water chillers as a zero-ODP substitute for CFC-12. A number of other zero, or near-zero, ODP refrigerants with volumetric flow rates in the range suitable for positive displacement chillers have been suggested. Examples are HFC-32, HFC-125, HFC-152a, HC-290 (propane) and R-717 (ammonia). These refrigerants are not attractive to designers of water chillers for commercial buildings.

Centrifugal compressors are the most efficient technology in their range of applications, 500 to perhaps 35000 kW (200 to several thousand tonnes capacity). The CFCs have been replaced by HCFC-123 and HFC-134a, respectively, but HCFC-22 is expected to be used in new equipment for at least another decade. Other refrigerants suggested for centrifugal chillers are HFC-143a (and maybe HFC-152a), and the fluoroethers E-134, E-143, and E-245ca. These compounds are either flammable or have no toxicity assessments at this time and in some cases have very limited thermodynamic data available. HFC-245ca is a potential long-term alternative to HCFC-123. More work is necessary to determine the efficiency of HFC-245ca as a refrigerant and to define any fire risks associated with its use in chillers. Nonflammable azeotropes containing HCFC-123 are another alternative for reducing the amounts of HCFC-123 used in chillers. Two isomers [ea and fa] of HFC-236 are being considered as replacements for CFC-114 which is used in specialty applications such as naval vessels.

Absorption is a tried and proven technology that is mass produced and well supported with a cadre of experienced technicians. This past decade, two-stage absorption chillers have been developed and produced with primary-energy-based efficiencies that approach 50% to 60% of those of vapour compression systems. Three-stage absorption systems are being developed to achieve efficiencies even closer to vapour compression systems. However, absorption chillers are inherently larger and considerably more expensive than vapour-compression chillers so absorption systems have had only limited market success in the western world. However one should emphasize that they are used to take advantage of waste heat so that they can be very economical in spite of the higher cost.

Retrofits

No substitute refrigerant can be used as a "drop-in" for CFCs with the exception of HFC-134a in some R-500 systems. HCFC-123 became available in 1989 to retrofit existing CFC-11 chillers. It is a more aggressive solvent than CFC-11. Non-metallic materials may have to be replaced with materials which are compatible with HCFC-123. HFC-134a became available in 1989 for retrofit in centrifugal chillers. Its use requires about 15% higher tip speeds than CFC-12, so impeller and/or gearbox replacement may be necessary. HCFC-124 has been suggested as an alternative to CFC-114 in centrifugal chillers such as those used in Naval applications, as has HFC-236fa. There are currently no satisfactory replacement refrigerants for use in existing equipment designed for HCFC-123 or HFC-134a, nor are any needed in the near future. For equipment now using HCFC-22, zeotropic and azeotropic mixtures of HFCs are being developed.

The HCFCs are required as transition and long term refrigerants respectively until at least the 2020-2030 period. HCFCs are needed to allow the most rapid phaseout of CFCs in those critical applications such as air conditioning and refrigeration where the HCFCs are the best alternatives available. Improved design and maintenance of systems to reduce leakage, design to minimise refrigerant charge quantities in systems, improved service practices, and reclaiming of refrigerant during servicing are practical and reasonable ways to reduce the emissions of HCFCs into the atmosphere, thus minimising adverse environmental effects.

HFC-134a will play an important role in the transition away from CFCs, particularly as a replacement for CFC-12. However, HFC-134a is not able to overcome the need for HCFC-123 and HCFC-22. There are no other good near-term alternatives to the continued use of HCFCs.

10.8 Transport refrigeration

Transport refrigeration includes refrigeration in ships, railcars, containers, swap bodies and road transport equipment, and also relates to transport air conditioning. New equipment and retrofit options have been identified, as have servicing needs and the impact of HCFC phaseout.

There are approximately 33,600 ships in excess of 300 tonnes gross, all of which use some forms of refrigeration. Fully refrigerated cargo ships and refrigerated container ships number about 1,500. HCFC-22 is virtually universal as the refrigerant for new cargo refrigeration equipment, but 1993 marked the return of ammonia in a few new ships. This has yet to be demonstrated as a commercially viable option for widespread use.

At the end of 1993 there were 252,000 integral refrigerated containers in use, of which about half were less than 5 years old. Since 1991 there has been an almost universal acceptance of HFC-134a for new units, and there have been moves to HCFC-22 and various blends such that there is no need for CFCs for new container equipment. Retrofit options for existing plant have been developed but have yet to be adopted on a large scale.

Manufacturing rates for road transport refrigeration equipment are around 100,000 per year, and new equipment from major producers is moving rapidly away from CFCs, including R-500 and R-502.

The currently available options for both retrofits and new equipment are bewilderingly large, and there is a need for much more application-specific testing to determine optimum solutions. This situation appears likely to become even more complex whilst manufacturers compete for the future refrigerants market.

There are no proven direct alternatives to HCFC-22, and HCFCs are likely to be required as components in economically viable retrofit blends.

10.9 Automotive air conditioning

The accelerated phaseout of CFCs has brought about a corresponding acceleration in the introduction of HFC-134a in new vehicles to the extent that full conversion in the developed countries was completed during 1994. Accelerated phaseout also created the need to address retrofitting existing CFC-12 vehicles (in the order of 290 million world-wide). This report deals principally with the technology and costs associated with servicing CFC-12 vehicles in the face of a dwindling CFC-12 supply and includes information from (and recommendations for), both developed and developing countries.

OEM vehicle manufacturers unanimously selected HFC-134a as their recommended retrofit refrigerant, although other refrigerants may exist and find use in the global marketplace. Refrigerants other than HFC-134a have not been supported by vehicle OEM's for several reasons: (1) they offer no advantage over HFC-134a; (2) there is essentially no time to adequately test and commercialise additional refrigerants; (3) they create the need for all service outlets to purchase yet another set of tools and equipment; and (4) they represent additional refrigerants with which the service industry must deal, thereby posing the real threat of contaminating existing CFC-12 and HFC-134a supplies, service equipment and MAC systems. The notion that a "drop-in" refrigerant may one day magically appear is not realistic and may even delay the application of retrofit technology currently developed while users wait for such a refrigerant to appear in the marketplace.

Refrigerant availability in any given use sector is difficult to forecast. Historically, the mobile air conditioning service industry has required a significant amount of refrigerant, which it will continue to require until the fleet is retrofitted or no longer in service. The CFC production phaseout will likely find those service industries requiring CFC-12 competing for the same limited supply.

Developing cost-effective and timely retrofit technology is a formidable task. A least-cost incremental retrofit is estimated to be about US $ 120. Higher cost scenarios, involving additional component replacements and/or additions are likely to be necessary for a significant percentage of vehicles to maintain acceptable durability and/or performance. It should be emphasised that these costs are exclusive of, and in addition to, the cost of repairing the problems that originally brought the system in for service. These repairs are estimated to average US $ 260. MAC system manufacturers and component suppliers are expected to provide retrofit information and components to the service industry in a timely manner.

Recycling CFC-12 and HFC-134a at the job site is a currently available technology and is a reality in many developed countries, and should be encouraged globally. The value of refrigerant recycling and proper servicing cannot be over-emphasised. The "gas-and-go" type of service, wherein leaks are not repaired and refrigerant is vented directly to the atmosphere during service, must be eliminated. Technicians that repair MAC systems should be technically qualified in basic diagnostic and servicing procedures.

The Society of Automotive Engineers (SAE) has developed technical documents covering equipment requirements for containment and recycling refrigerants used in mobile A/C systems. SAE documents also include technician service and retrofit procedures that can provide guidance for Article 5 countries.

AFEAS and the U.S. Department of Energy has recently collaborated on evaluating the technology status of carbon dioxide, zeolite/water, the air cycle, and Stirling cycle for potential use in mobile A/C systems. These technologies are currently in their infancy and face significant technical hurdles which must be overcome before they can be considered to be commercialisable.

10.10 Heat pumps (heating only and heat recovery)

Heating-only heat pumps are used for space and water heating in residential, commercial/ institutional and industrial buildings. In industry, heat pumps are used for heating of process streams, heat recovery and hot water/steam production. They are often an integrated part of industrial processes, such as drying, evaporative concentration and distillation. Virtually all heating-only heat pumps are electric closed-cycle compression type systems.

The vast majority of heating-only heat pumps in buildings are located in Western Europe, as most heat pump installations in Japan, USA and Canada are reversible air conditioners. It is estimated that the total number of heating-only heat pumps in these market sectors (including district heating) is roughly 1.4 million units, with a total heating capacity of about 11,000 MW and an annual heat supply of 25 TWh/year. The corresponding figures for industrial heat pumps are 7,000 units, 2,500 MW and 12 TWh/year.

HCFCs are generally accepted as a part of the solution for a rapid CFC phaseout, and HCFC-22 is the most important refrigerant in this category. Many European countries are discussing regulations on HCFCs with a view to phasing them out more rapidly than has already been agreed under the Montreal Protocol. (e.g., Germany, Sweden and maybe Italy will ban the use of HCFCs in new equipment from the year 2000).

HFC-134a is currently applied for retrofitting of existing heat pumps using CFC-12 and for charging of new installations. HFC-134a heat pump technology is considered fully mature for new systems. The demand for HFC-134a is expected to increase substantially in the next years. Moreover, other HFCs as well as HFC blends are expected to be available towards the end of the decade, thus resulting in a further increase in HFC consumption.

Ammonia has recently seen an increasing number of experimental applications for large capacity heat pump systems in Europe. Halt in CFC production and further technology development are expected to accelerate its commercialisation and market penetration in Europe, as well as in Japan and the United States. Ammonia technology for small capacity heat pumps is expected to be available by the turn of the century.

Propane is currently used in experimental, residential, heat pumps in Europe. Technology development and improved safety measures are assumed to reduce safety hazards and improve public acceptability. Hence, propane, other hydrocarbons as well as hydrocarbon blends are expected to play an increasingly important role in the mid to long term, especially in small and medium capacity heat pumps.

Carbon dioxide is a promising long-term natural refrigerant, but is not expected to become of much commercial importance until the late 1990s.

Heat pumps for heating only purposes have a negligible impact on total refrigerant consumption volumes worldwide (<1%). The estimated refrigerant volume is approximately 11,000 tonnes, with 60% CFCs and 40% HCFCs (1993). Assessments indicate that the total annual refrigerant demand for heat pumps will be about 2,300 tonnes in the year 2000, of which 70-80% are HFCs and the rest HCFCs and "natural refrigerants".

If 60% of the refrigerants in scrapped and retrofitted equipment can be recovered, approximately 2,300 tonnes of CFC and 1,150 tonnes of HCFC will be made available for reuse between the year 1995 and 2000. This is about 20% more than the expected demand for CFCs for servicing of existing heat pump installations.

10.11 Refrigerant conservation

Until a few years ago, refrigerant conservation was considered to be important only for proper system functioning. Venting refrigerants during service was a usual practice. The ozone layer depletion and the need to limit environmental effect of refrigerant emission changed this. As well, the 1991 revision of the Montreal Protocol that included a phaseout schedule for HCFC refrigerants extended the interest of conservation. To avoid any direct impact of refrigerants on environment through their emission, refrigerant conservation is a major consideration in refrigerating system design, installation, and service. Conservation deals also with the needs for servicing existing equipment for both developed and Article 5 countries.

As the most direct way to reduce emissions to the atmosphere, refrigerant conservation should be promoted by governments which are Parties to the Protocol. Tools may include research and development, information dissemination, financial incentives, and direct regulations. It should start, anyhow, with regulations making recovery compulsory. Without this basic regulation, experience shows that refrigerant recovery will not be carried out.

Refrigerant conservation has three basic elements:

- to properly design and install new equipment so as to minimise actual or potential leaks;
- to leak-tighten existing systems so as to reduce emissions, in case of continued use of CFCs or retrofit to HCFCs or HFCs;
- to improve service practices, including recovery, permitting continued system operation with reduced need to add refrigerant.

Good service practice can significantly reduce refrigerant loss by regularly checking the systems to find and repair leaks and by recovering the refrigerant each time the system has to be opened. Training of installers, operators, and service operators is required to accomplish proper cooling system operation and containment.

Availability of recovery equipment has significantly increased over the last three years. Standards have been written in order to measure the performances of equipment, and methods have been developed to make recovery more efficient.

Refrigerant removed from a refrigerating system may be returned to the same system after recycling. It may be required that refrigerant be reclaimed before it can be reused in another system to make sure that the contaminant level is consistent with the system operation. In all cases, refrigerant reuse requires taking measures to avoid mixing refrigerants. Refrigerant which is too contaminated for reuse will ultimately have to be destroyed. At present, high temperature incineration is about the only practical method of destroying CFC and HCFC refrigerants, but other technologies may emerge in the future.

In Article 5 countries, priorities should be given to maintaining systems in proper operating condition including tightening up systems by finding and repairing leaks and recovering refrigerant for reuse before servicing systems. Strong government incentives will be necessary in order to reach effectiveness.

10.12 Developing country aspects

During the last couple of years, many projects have been launched in the Article 5(1) countries. These projects cover both technology, reclaim and training projects. The effort ahead shall concentrate on training, as this subject requires highest priority. Parallel with that effort, changes to new technology, collection and reclaim of CFC, HCFC, etc. are to be continued.

It is worth noting that considerations are extremely essential on which new technology will be utilised, especially the issue of the new types of refrigerants and also the utilisation of flammable refrigerants. The background of this consideration is that if the change in technology does not correspond to a specific Article 5(1) country's situation, in relation to both the home market and export, it may result in an additional change in technology within a few years.

Further more, it is considered desirable that a more stringent legislation in the Article 5(1) countries is implemented within the fields of refrigerants, refrigerating plants and related leakage rates. This is necessary in order to complete the essential changes in refrigeration technology in a successful way.

10.13 Research coordination and information dissemination

This section enumerates the types of information required to ensure that the phaseout of CFCs and HCFCs proceeds in an orderly and cost effective manner, provides a discussion of where this type of information may be obtained, and provides a listing of some of the key areas in which co-operative research and developmental efforts are needed. Both short- and long-term approaches to CFC and HCFC phaseout are being developed. This section points out the importance for ensuring that available information includes a discussion of both the problems associated with the near-term ban on CFC consumption (conservation, recycling, transitional replacements), as well as information on long-range alternatives. It also highlights the need for information to address the needs of both Article 5 and developed countries.

The audience for this section includes anyone responsible for policy development and equipment replacement decisions, such as government environmental officials, equipment and refrigerant manufacturers, installation and maintenance personnel, building owners and managers, consulting engineers, and facility operators. This section emphasises the need for reliable and unbiased information that includes success stories as well as analyses of programs that have been unsuccessful.

The types of information addressed in this section include:

- basis scientific information on stratospheric ozone depletion, global warming, and the role of ozone depleting substances (ODS) in these two processes;
- data on basic refrigerant properties, as described in section 2: system engineering, and equipment design and manufacturing;
- retrofitting of existing equipment, service requirements, and training;
- regulations, and

- financing mechanisms.

The section also provides a listing of where some of this information may be obtained, from both governmental and non-governmental sources. Some of the issues associated with information dissemination are discussed in the framework of providing recommendations for how information should be compiled, formatted, catalogued, abstracted and simplified for optimal use. Finally, the section presents a listing of some sources of current research on alternative refrigerants, energy efficiency and refrigerant safety.

10.14 Historical global CFC consumption future demand and supply from new production and recycle

This sections provides historical data for CFC use, as well as potential demand for CFCs through the year 2000.

It is estimated that the developed world's use of CFCs has declined from 862 thousand metric tonnes (kt) to 302 kt between 1986 and 1993; or 65%. Total global CFC use is estimated to have declined from 1133 kt to 643 kt between 1986 and 1992; or 43%. In this same time-frame, CFC use by developing countries, and countries with economies in transition, appears to be fairly constant at 250-270 kt/year.

From 1986 through 1992, global CFC refrigerant use has declined slightly; from 250-275 kt/year (after peaking at about 300 kt in 1988-1989) to about 230 kt/year. The developed world's CFC refrigerant use was 208 kt/year in 1992 and declined to 130 kt/year in 1992, a drop of 38%. In a comparable time-frame, the non-developed or rest of the world's use of CFC refrigerants essentially doubled to about 100 kt in 1992. It seems likely that total CFC use, and particularly CFC refrigerant use in the "rest of the world", will be essentially equal to or greater than the developed world in 1994. See Figure 2 for a graphical picture. The change in CFC refrigerant use within the developed world between 1986 and 1993 is an interesting statistic:

- U.S. use declined by 1/2; 132 kt to 65 kt
- Japan use declined by about 1/3; 24.3 kt to 17 kt
- The E.U. use increased from 29.9 kt to 35.6 kt

The significant difference in reductions in three regional markets (U.S., Japan, and the E.U.) may be the result of the significant differences in government programs. The most aggressive efforts included: large excise taxes, "no venting" regulations, limits on supply that were below Protocol limits, as well as encouragement to use all available safe alternatives.

The total global CFC refrigerant use in 1994 is about 230 kt/year, with the developed world's declining use offset by increasing use in the "rest of the world". Over 85% of this continued CFC refrigerant use is for servicing existing equipment; with more than one-half involved in the vast array of CFC-12 food storage lockers, perishable food dispensers, domestic appliances, commercial food or perishable food storage, etc.

Experience to-date suggests that refrigerants tendered for recycle at central collection facilities are less than 3% of the annual refrigerant sales volume. The fact that overall refrigerant demand in several large markets has fallen 20-50% suggests that internal recovery and recycle is being practiced by mechanics servicing the equipment.

The potential world supply of CFCs after 1995 when all developed world new production will cease except as required by Article 5 countries has been estimated at 338 kt/year more than adequate for refrigeration and air conditioning needs serviced by CFCs 11 and 12. Shortages of specialty CFCs (i.e., CFC-13, 113, 114, and 115) are likely, unless users have inventories purchased in advance of most of the developed world plants' shutdown.

10.15 Historical global HCFC consumption - future demand

This section provides historical data for HCFC use, as well as potential demand for HCFCs through the year 2000.

Non-feedstock HCFC-22 use has been in the 230 kt to 260 kt range for the last 5 years. HCFC-22 refrigerant use in this time-frame has been 205 kt to 220 kt. National no-venting regulations in the world's largest HCFC-22 market has blunted HCFC-22 growth and it is projected that there will be flat or even negative growth globally as recycling and conservation become common practice globally in the traditional large HCFC-22 markets.

Miscellaneous uses of other HCFCs (123, 124, 141b, 142b) as refrigerants ares expected to be very modest, primarily as retrofitting fluids in existing equipment; 15-25 kt/year is a reasonable estimate for the balance of the decade.

HCFC-22, 141b, and 142b as blowing agents, propellants, and cleaning agents are estimated to be about 127 kt in 1994, peaking at about 150 kt over the next four years and then gradually declining as users perfect technologies that provide desired performance without use of HCFCs.

The global demand for all HCFCs is projected at about 335 kt/year in 2000, comparable to 1993-1994 and 10% below the peak that will occur in the next 2-4 years. The peak is associated with the CFC phaseout, and the late 1990's decline is due to greater use of non-ozone depleting technologies; primarily HFCs.

11 Summary of the Report of the Solvents, Coatings and Adhesives Technical Options Committee

11.1 Developed country progress in eliminating ozone-depleting solvents

Most developed country suppliers and consumers of ozone depleting solvents are halting production and use earlier than mandated or expected. A few enterprises have made unwise first choices of alternatives and substitutes and are changing to better options.

However, significant problems exist in the European Union (EU), where many companies began their investments too late and may not be able to halt their use prior to the 1 January 1995 EU phaseout of production. Furthermore, some large companies in developed countries may have been over-confident that their uses would qualify as essential and consequently may not have allowed enough time for a smooth transition. Varying sizes of enterprises, but especially small- and medium-sized ones, are identified in many developed countries as possibly being unaware, unprepared, and financially unable to make necessary investments in time to avoid chemical shortages and price increases that could jeopardize their businesses.

Procrastination in implementing alternatives and substitutes could lead to significant price increases for stockpiled and recycled ODSs manufactured prior to the phaseout. Dramatic price increases could stimulate illegal markets in imported solvents. In the immediate future, shortages of ozone-depleting substances (ODSs) for solvent applications could cause companies to switch to chlorinated solvents and/or HCFCs, if allowed, because these solvents can often be used in existing equipment.

11.2 Military progress

In January 1994 the North Atlantic Treaty Organization (NATO) held its 2nd international conference on "The Role of the Military in Protecting the Ozone Layer". Participants from Algeria, Belarus, Belgium, Brazil, Canada, Denmark, France, Germany, Hungary, India, Italy, Japan, Kenya, Latvia, Lithuania, Norway, Pakistan, Poland, Portugal, Romania, Russia, Spain, Slovakia, Sweden, Taiwan, Thailand, Netherlands, Turkey, Ukraine, United Kingdom, United States, and Uruguay attended the meeting. NATO members reported that they are meeting or exceeding the production phaseout goals of the Montreal Protocol and EU members reported that they are meeting their more stringent goals. Part of the reason for this progress has been the leadership of policy makers in some ministries of defence who realized that global environmental protection is part of national security and also recognized that they cannot continue to depend on chemicals that will be unavailable or increasingly expensive.

Germany, Norway, and Sweden reported that they have virtually eliminated the use of ozone-depleting solvents in military applications.

German, Swedish, UK, and US participants reported comparable progress in identifying and documenting alternatives and substitutes for civilian aircraft maintenance including options that provide equal or improved cleaning, surface preparation, and bonding. The International Cooperative for Ozone Layer Protection (ICOLP) announced plans to invite U.S. Environmental Protection Agency (EPA) and the National Aeronautics and Space

Administration (NASA) to join their global project to phase out ODSs in aerospace operations. NASA and U.S. EPA are considering the proposal.

The meeting resulted in several recommendations being made to NATO:

- Share information on critical uses (e.g. gaseous and liquid oxygen systems, guidance systems, rocket motors) via electronic data-bases, publications, workshops and informal working groups.
- Foster and support streamlined universal qualification processes and procedures.
- Revise the existing military documentation.
- Further investigation, certification, and publication of alternatives and substitutes for unresolved applications including critical adhesive bonds in rocket motor manufacturing, cleaning and verification of gaseous and liquid oxygen systems, and other specific precision cleaning such as gyroscope bearings in space systems that must operate for many years without maintenance.
- Speed awareness and introduction of proven technologies by utilizing "tiger teams" of experienced engineers and scientists to help implement these technologies in military applications.

11.3 Developing country progress

In some cases, technology cooperation with developing countries has already been highly successful or has prepared countries to take prompt action once incentives and financing are in place. Examples include Mexico, Thailand, Turkey, and Malaysia. An important conclusion from investigations of solvent use in developing countries is that enterprises must be motivated and prepared to accept new technology. This motivation can result from government regulation, a clearly articulated industry phaseout strategy, price increases, product shortages, or supply uncertainty for ozone-depleting substances. Some technology cooperation efforts have been prematurely attempted in countries where enterprises and national governments were not prepared, and as a consequence little actual investment progress has been made.

Some regional and national conferences and workshops have not been as successful as they could have been because the preconditions for change had not been met. The Committee recommends that conference planners more completely involve local industry, industry associations, and chambers of commerce in the planning and that they determine whether the preconditions for change are in place. If it is determined that a conference is useful, conferences should be organized and announced far in advance. It has been the experience of the Committee in developed and developing countries that representatives of small- and medium-sized solvent-using enterprises do not travel long distances for meetings based on general presentations. They are short of funds and their manufacturing engineers are very busy. This makes ensuring the presence of a motivational framework all the more important.

One problem common to all countries, but especially developing countries, is that domestic small- and medium-sized enterprises that use ODSs are difficult to identify, may not welcome government officials, and may not be easy to convince that a change is necessary. It is likely that many of such users will only make changes when the price increases, when shortages develop, when domestic regulations are in place, or when multinational companies require suppliers to phaseout.

11.4 Concerns of unannounced changes in speciality products

The Committee cautions that manufacturers may eliminate ODSs from products without notifying customers. There is the possibility that the manufacturer may not appreciate that their product is used in a particular application where the ODSs provided a necessary performance characteristic that is not duplicated by the reformulated product. Use of such reformulated materials and products under these circumstances could be costly or dangerous to life and health. The solution is for manufacturers of speciality products to better communicate to end-users, changes in product ingredients and to cooperate with end-users on performance testing of the new products.

Some Parties may have interpreted process agent use of controlled substances as subject to phaseout. Other Parties may have interpreted such use as feedstock not subject to the phaseout. In 1994 the Committee was unable to recommend exemptions for process agent use under the Essential Use Criteria.

At the October 6-7, 1994 Meeting of the Parties to the Protocol, it was decided:

> "...for an interim period of 1996 only, (Parties may) treat chemical process agents in a manner similar to feedstock, as recommended by the Technology and Economic Assessment Panel, and take a final decision on such treatment at their Seventh Meeting;"(Decision VI/10)

The Parties requested the Technology and Economic Assessment Panel (TEAP):

> To identify uses of controlled substances as chemical process agents, to estimate emissions and ultimate fate, and to evaluate control technologies;
>
> To evaluate alternative process agents or technologies or products available to replace controlled substances in such uses; and to
>
> To report findings not later than March 1995. The Panel has asked the government of Sweden to organize and finance a special working group to complete this work.

11.5 1994 Nominations for Essential Uses

The Committee reviewed nominations from Austria, Belgium, Canada, Denmark, European Commission (EC), Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, United Kingdom, and the United States. In all but laboratory and analytical uses and Space Shuttle rocket motor manufacturing the Committee was unable to recommend the nominations because there are technically and economically feasible alternatives and substitutes and/or because controlled substances are available in sufficient quantity and quality from existing sources. The Committee also found that many requests were insufficiently supported with technical data.

11.6 HCFC

Few large scale current uses of HCFCs have been reported for solvents, coatings, or adhesives. In the near term HCFCs may be necessary as transition substances in some limited and unique applications including:

- cleaning delicate materials such as cultural heritage and archival property
- cleaning assemblies or components with sensitive materials or particular soils
- cleaning certain oxygen systems
- cleaning where explosive or flammable conditions are possible
- as a carrier of oil in precision applications.

In countries where HCFCs are prohibited, enterprises may, in certain specific cases, select perfluorinated carbons (PFCs) as an adjunct to specialized cleaning systems. PFCs have extremely long atmospheric lifetimes and have potent global warming potentials (GWPs) and should therefore be avoided where possible.
The Committee does not recommend the use of HCFC-141b to replace 1,1,1-trichloroethane as a solvent. A recommendation is not possible because HCFC-141b has an ozone-depletion potential (ODP) comparable to 1,1,1-trichloroethane and is not technically suitable for many cleaning applications.

It is estimated that HCFC-141b and HCFC-225 together will not replace more than 1 percent of global CFC-113 uses unless HCFC-225 becomes a substitute for CFC-113 in dry cleaning, which could increase use to approximately 5 percent. In some countries with active HCFC sales efforts, approximately 5 percent of CFC-113 solvent use (excluding dry-cleaning which may increase use) may be replaced with HCFC-141b. It is estimated that HCFCs may replace 1-5 percent of 1986 CFC-113 and 1,1,1-trichloroethane use as transitional substances and where no alternatives or substitutes are currently available.

The Committee cautions that there may be essential uses of very small quantities of ozone-depleting solvents that are not yet identified by the Committee, national governments, product distributors, and possibly the manufacturers themselves. However, it is expected that these uses will be identified as the accelerated phaseout in the EU is implemented and as production is halted. Stockpiled and recycled sources may be adequate to supply these uses.

11.7 Price increases and shortages of ozone-depleting solvents

CFC-113 is produced primarily as a solvent with certain amounts sold as a feedstock for production of HFC-134a and some plastics. When CFC-113 sales in solvent uses are halted in the EU in 1995, and in all developed countries by 1996, the market may not be sufficient for developed country manufacturers to supply developing country markets.

CFC-113 is currently manufactured in two developing countries -- China and India -- and production facilities in South Korea and Taiwan are believed to be currently inactive.

Since 1,1,1-trichloroethane is produced as a feedstock for HCFC-141b and HCFC-142b, it will be more readily available than CFC-113 after 1996 for export to developing countries for their domestic needs, subject to Protocol restrictions.

It is the consensus of the Solvent, Coatings and Adhesives Technical Options Committee that quality grades of CFC-113 and 1,1,1-trichloroethane will be in uncertain supply after 1996 and that it will be prudent for enterprises in developing countries to move quickly to reduce and eliminate dependence on these chemical substances when cost-effective options are available. European, Japanese, and U.S. chemical manufacturers, distributors, and customers may have residual chemical supplies produced under national Protocol quotas or under Basic Domestic Needs quotas that may be marketed to developing countries if sales are less than expected in their developed country markets. This oversupply is less likely in the United States where taxes on stored ozone-depleting substances discourage oversupply.

A variety of alternative substances and technologies are currently in use or under development to facilitate the phaseout of CFC-113 and 1,1,1-trichloroethane. These alternatives include no-clean technologies, aqueous and semi-aqueous cleaning, other hydrocarbon solvents, non-ozone-depleting chlorinated solvents, HCFCs, perfluorocarbons, and a growing number of non-solvent cleaning processes.

No-clean technologies represent the optimum alternative and have been applied in an increasingly large number of electronics manufacturing applications in recent years. Nevertheless, research and testing of no-clean manufacturing processes is ongoing in the hope of making them viable alternatives in a wider variety of uses. Second to no-clean with respect to environmental protection is aqueous or semi-aqueous cleaning. The major drawbacks of these alternatives may be high energy consumption and wastewater treatment costs, depending on the process, requirements, and legislation.

HCFCs, though their use is transitional, are important alternatives to CFC-113 and 1,1,1-trichloroethane solvent use in applications for which no other viable alternative exists. Because of their lower ozone-depletion potential (ODP), HCFCs with a short lifetime are preferred to those with longer lifetimes. The ODP of all HCFCs is lower than the ODP of CFC-113. However, HCFCs should be used as substitutes for 1,1,1-trichloroethane only if the ODP of the HCFC substitute is lower than 0.10 and if their emissions are controlled using the best available technology. In addition, the 1992 Copenhagen Amendments to the Montreal Protocol require that production and consumption of HCFCs, as defined in the Protocol (Annex III G. Article 2F of UNEP/OzL. Pro. 4/15), must be reduced by 99.5% by 2020 and completely phased out by 2030. Thus, HCFCs are a valid alternative in certain limited applications while other, long term alternatives are being developed.

11.8 Sector progress

11.8.1 Electronics Cleaning

The electronics industry, which was heavily dependent on ozone-depleting solvents until recently, is fortunate to have the widest range of substitute materials and processes available. There is no technical reason why any company, large or small, in a developed or developing nation, should not be able to move away from such solvents immediately. Economic considerations, reported in previous editions (UNEP 1989, 1991), have shown that most substitute processes for this industry are less costly to run and, most often, give improved technical quality. On the other hand, relatively large investment capital is sometimes required to obtain the required results and this could be an obstacle, especially for small companies manufacturing "hi-tech" electronics.

To substitute for CFC-113 in defluxing, there is a large choice of processes, equipment, and materials commercially available for production units of all sizes. Where there are no technical specifications that require post-solder cleaning, "no-clean" techniques are often the most economical. This technique is recommended where the reliability criteria can be met. Where cleaning is a requirement, the use of water-soluble chemistry has generally proved to be preferable to most other processes, although it is not a universal solution. There is an adequate choice of other techniques where neither of these can be applied.

The Solvents, Coating and Adhesives Technical Options Committee do not recommend the following processes in electronics manufacture for funding under the provisions of the Montreal Protocol Multilateral Fund:

- *HCFC-141b for defluxing printed circuits*
- *Vapour-phase reflow soldering*
- *Vapour-phase drying of heavy organic solvents using PFCs*
- *Vapour-phase drying of water using HFCs or PFCs.*

11.8.2 Precision Cleaning

Precision cleaning applications are characterized by the high level of cleanliness required to maintain low-clearance or high-reliability components in working order. They are used in a variety of manufacturing industries, such as in aerospace, microelectronics, automotive, and medical. Several factors define the applications where a precision cleaning process is required. Some of these factors are:

- high standards for the removal of particulates or organic residue
- components constructed of chemically-sensitive materials
- components with physical limitations, such as geometry or porosity, which limit the ability to remove entrapped fluids like water
- high-cost components or components requiring high-reliability

CFC-113 and 1,1,1-trichloroethane have evolved as the preferred solvent cleaning method in precision cleaning because of their chemical inertness, low toxicity, non-flammability, low surface tension, and low water solubility. However, to eliminate CFC-113 and 1,1,1-trichloroethane use, a number of companies have tested and implemented alternative cleaning methods. Possible alternatives include solvent and non-solvent options. Solvent options include other organic solvents (such as alcohols and aliphatic hydrocarbons), perfluorocarbons, HCFCs and their blends, and aqueous and semi-aqueous cleaners. Non-solvent options include supercritical fluid cleaning, UV/Ozone cleaning, pressurized gases, and plasma cleaning. Solvent use may also be reduced by controlled planning of repetitive or multiple cleaning operations.

11.8.3 Metal Cleaning

Metal cleaning is a surface preparation process that removes organic compounds such as oils and greases, particulate matter, and inorganic soils from metal surfaces. Metal cleaning prepares parts for subsequent operations such as further machining and fabrication, electroplating, painting, coating, inspection, assembly, or packaging. Parts may be cleaned multiple times during the manufacturing process.

The control approaches available for metal cleaning operations include solvent conservation and recovery practices and the use of alternative cleaning such as solvent blends, aqueous cleaners, emulsion cleaners, mechanical cleaning, thermal vacuum de-oiling, and no-clean alternatives. Alternatives to CFC-113 and 1,1,1-trichloroethane must be selected and optimized for each application given the varying substrate materials, soils, cleanliness requirements, process specifications, and end uses encountered in metal cleaning.

11.8.4 Dry Cleaning

Dry cleaning enables the cleansing and reuse of fabrics that cannot be cleaned by alternative methods. The inherent environmental friendliness of restoring freshness to soiled articles and garments is matched by extreme efficiency in terms of solvent and energy use in the dry cleaning process itself. Organic solvents are used to clean fabrics because, unlike water, they do not distort some natural and synthetic fibres. Water cleaning of many materials can affect the stability of fabric, lining, and interlining and may cause stretching or shrinkage.

A number of solvents can be used as alternatives to CFC-113 and 1,1,1-trichloroethane in dry cleaning operations. Perchloroethylene, the most widely used dry cleaning solvent, has been used in this application for over 30 years, during which time the systems for its safe use have become highly developed. The flammability of petroleum solvents effectively precludes their use in shops, although with proper precautions, they can be a substitute for CFC-113 on many fabrics. Petroleum solvents include white spirit, Stoddard solvent, hydrocarbon solvents, isoparaffins, n-paraffin, etc. A number of HCFCs and HCFC blends are currently available commercially for use in solvent applications. These include HCFC-123, HCFC-141b, and HCFC-225. These HCFCs have good stability, appropriate solvency, and non-flammability and some HCFCs are suitable for cleaning those delicate fabrics that currently depend on CFC-113. It should be noted, however, that HCFCs are transitional alternatives subject to a phaseout under the Montreal Protocol by the year 2030. Other classes of chemicals such as isoparaffins, solvents derived from sugar cane, and hydrocarbon/surfactant blends are theoretically possible alternative dry cleaning solvents. More research, however, is necessary to determine their feasibility for dry cleaning.

11.8.5 Adhesives

1,1,1-Trichloroethane is used as an adhesive solvent because it is non-flammable, dries rapidly, does not contribute to local air pollution, and performs well in many applications, particularly foam bonding. The rubber binders used in 1,1,1-trichloroethane adhesives are soluble in other solvents, such as acetone, ethyl acetate, heptane, and toluene. Although there has been a general trend in the U.S. and Western European adhesives industries to replace organic solvent-based adhesives with solvent-free types, one alternative is to return to earlier solvent formulations.

Some adhesives use water, in lieu of organic solvents, as the primary solvent. Recent literature on water-based adhesives suggests that there is still much debate about the overall effectiveness of water-based adhesives for many end uses.

The Committee D-14 of the American Society for Testing and Materials (ASTM) defines a hot melt adhesive as one that is applied in a molten state and forms a bond upon cooling to a solid state. Hot melt Pressure-Sensitive Adhesives (PSAs) now compete with water-based acrylics in outdoor applications. They have been used on paper labels for indoor applications since 1978.

Radiation curing is a production technique for drying and curing adhesives through the use of radiant energy such as ultraviolet (UV), infrared (IR), electron beam (EB), gamma, and x-rays. Radiation cured adhesives are especially well adapted for pressure sensitive tapes. One drawback is that adhesive curing is only possible in the "line of sight" of the radiant energy.

One way to lower volatile organic compound (VOC) emissions when using solvent-based adhesives is to increase the percent solids in the formulation. High solids adhesives have good performance characteristics, including initial bond strength comparable to that of 30 percent solids adhesives in medium and high demand applications and can be applied using existing equipment at normal line speeds with minor modifications. In other application areas, such as bonding rubber assemblies, high solids adhesives have not been as successful.

One-part epoxies, urethanes, and natural resins are often supplied as powders that require heat to cure. Powders are only used for non-pressure-sensitive applications. One advantage of the powder form is that no mixing or metering is necessary. However, powders must be refrigerated to maximize shelf life.

Moisture cure adhesives and reactive liquids can be applied as 100 percent non-volatile solid and liquid systems. These adhesives are composed entirely of binding substances, modifiers, and fillers (i.e., they have no carrier or solvent). Moisture cure adhesives cure upon exposure to the humidity in the ambient air; this type of adhesive requires application in a humid environment and might not work well in dry climates. Some two-component adhesives use reactive solvents which form part of the cured mass and thus do not depend on evaporation. In use, one solution consisting of an elastomer colloidally dispersed in a monomer is cured by a second solution through a free radical chemical polymerisation, thereby creating the bond .

11.8.6 Coatings and Inks

1,1,1-Trichloroethane is used by manufacturers, printers, and users of protective and decorative coatings and inks. CFC-113 use in the production of coatings or inks is negligible. In coatings, 1,1,1-trichloroethane is used alone or combined with other solvents to solubilize the binding substance which is usually composed of resin systems such as alkyd, acrylic, vinyl, polyurethane, silicone, and nitrocellulose resin. Inks are used to print items ranging from wallpaper to dog food bags to beverage bottles and cartons. Many of these uses involve the application of coloured ink to a film (or laminate) in the flexible packaging industry.

Some coatings contain water rather than organic solvents. Recent advances in water-based coating technology have improved the dry-time, durability, stability, adhesion, and application of water-based coatings. Primary uses of these coatings include furniture, electronics in automobiles, aluminum siding, hardboard, metal containers, appliances, structured steel, and heavy equipment. Water-based inks for flexographic and rotogravure laminates have been successfully developed and have overcome technical hurdles such as substrate wetting, adhesion, colour stability, and productivity.

Although high-solid coatings resemble conventional solvent coatings in appearance and use, high-solid coatings contain less solvent and a greater percentage of resin. High-solid coatings are currently used for appliances, metal furniture, and a variety of construction equipment. The finish of high-solid coatings is often superior to that of solvent-based coatings, despite the fact that high-solid coatings require much less solvent than do solvent-based coatings.

Powder coatings contain the resin only in powder form and thus have no solvent. While powder coatings were first used only for electrical transformer covers, they are now used in a large number of applications, including underground pipes, appliances, and automobiles.

Ultraviolet light/Electron beam (UV/EB)-cured coatings and inks have been used in very limited applications over the last 20 years, but their use has seen a dramatic increase in recent years. Several of the markets in which UV/EB-cured coatings and inks have been used more frequently in recent years are flexographic inks and coatings, wood furniture and cabinets, and automotive applications. One major limitation to the use of UV/EB-cured coatings and inks is outdoor durability. This is an especially important consideration in automotive applications.

11.8.7 Aerosols Solvent Products

1,1,1-Trichloroethane functions as either an active ingredient (e.g., degreaser or cleaner) or as a solvent in aerosol product formulations. Though most of the aerosol applications traditionally used 1,1,1-trichloroethane as their solvent, there are a small number of products which made use of CFC-113 as well. Most aerosol products currently employing CFC-113 and 1,1,1-trichloroethane can be reformulated with alternative compounds. Except for water, some HCFCs, and non-ozone-depleting chlorinated solvents (e.g., trichloroethylene, perchloroethylene, methylene chloride), all of the substitute solvents currently available are more flammable than 1,1,1-trichloroethane. The flammability is also a function of the propellant; butane and propane being more flammable than carbon dioxide, nitrous oxide or the traditional CFC-11/CFC-12 mixture.

Alternative solvents currently exist for virtually all aerosol solvent applications of CFC-113 and 1,1,1-trichloroethane. However, while some of these alternatives are functional, they are considered to be less than optimal for a variety of reasons. For example, in applications where a strong solvent is required, but the use of a flammable solvent would pose serious safety risks, substitutes may include only HFCs, HCFCs, and chlorinated solvents. While these solvents would be functional, HCFCs contribute to ozone-depletion, and chlorinated solvents are toxic and may pose health risks to workers and users of a product.

CFC-113 and 1,1,1-trichloroethane use in aerosols can also be reduced if alternative means of delivering the product are developed. Two examples of these alternative methods are: (1) a manual "wet-brush" (recirculating liquid) system, as a substitute for aerosol brake cleaners used in repair shops, and (2) increased use of professional dry cleaning services as a substitute for the use of aerosol spot removers.

11.8.8 Other Solvent Uses of CFC-113, 1,1,1-Trichloroethane, and Carbon Tetrachloride

Some amount, in most cases relatively small quantities, of CFC-113, 1,1,1-trichloroethane, and carbon tetrachloride are employed in a number of industry and laboratory applications. The application areas include drying of components, film cleaning, fabric protection, manufacture of solid rockets, laboratory testing and analyses, process solvents, semiconductor manufacturing, and others.

The Committee consensus is that by 1996, in accordance with the Montreal Protocol, most of the CFC-113, 1,1,1-trichloroethane, and carbon tetrachloride used for these applications can be replaced by the alternatives.

In the applications of laboratory analyses and in the manufacture of a specific large scale solid rocket motor, the Parties have granted an exemption for continued use of specified ozone-depleting solvents for 1996 and 1997. The exemptions are subject to review and alternatives are being investigated.

In the case of use of ozone-depleting substances as process chemicals, there are also a number of alternatives identified in this report. In addition, an in-depth review of alternatives is planned for completion and presentation by the Technical and Economic Assessment Panel to the Parties by early 1995.

11.9 Progress in eliminating ods from rocket motors

Ozone Depleting Substances (ODSs) have been routinely used globally for decades in the manufacture of space launch vehicle solid rocket motors (SRMs). The primarily ozone-depleting solvents used are 1,1,1-trichloroethane (TCA or methyl chloroform) and CFC-113. These substances are used because of their excellent cleaning properties, low toxicity, chemical stability and non-flammability.

In the United States, large solid rocket motors (SRMs) are used to launch into space communication, navigational and scientific satellites and the manned Space Shuttle orbiters. Large SRMs include the existing Titan IV SRM as well as its upgraded version called the SRMU and the Space Shuttle redesigned solid rocket motor (RSRM).

Despite these technical safety and reliability challenges, the SRM industry has successfully tested, approved, and implemented significant ODS elimination. Since 1989, the four US manufacturers of large SRMs have eliminated over 1.6 million pounds of ODS use per year. Current (1994) ODS usage is less than 48 percent of the use in 1989. Usage in 1995 is estimated to be less than 22 percent of 1989, and manufacturers have committed to complete elimination of ODSs within the next few years.

11.9.1 Update on the Essential Use Applications

NASA/Thiokol was granted an essential use production exemption for 1996 and 1997. NASA/Thiokol have proceeded with their phaseout and are ahead of schedule for eliminating non-essential uses and investigating additional alternatives and substitutes. However, at this time NASA/Thiokol has not identified any acceptable substitutes that would reduce their essential use below the previously calculated amounts.

The Solvents, Coatings, and Adhesives TOC reported in the March 1994 Report that it was likely that all manufacturers of solid rocket motors use ODSs. The Committee has confirmed that other U.S. and European solid rocket motors use these substances and that these organizations are expected to nominate additional essential uses by January 1, 1995 for decision in 1995.

The U.S. Titan program is working to completely eliminate the use of ODSs and has invested substantial resources in successfully developing alternatives to ODS use. The prime contractor and the major manufacturers of Titan IV vehicle components will reduce all ODS use by 99 percent, from 1.33 million kg in 1989 to 9,200 kg in 1996. Four small-quantity ODS uses are critical to the success of the Titan SRMU. These are (1) surface preparation to ensure effective bonding of the internal insulator to the composite case, (2) surface preparation to ensure effective attachment of breather cloth to the insulator to permit uniform curing, (3) surface preparation to ensure effective bonding of the propellant to the insulator, and (4) dispersing propellant cure catalyst during propellant mixing. The quantity of ODS necessary to complete SRMU manufacture for the final nine flight sets is 3,660 kg per year or less for 1996 through to 1999.

Both CFC-113 and TCA are used in the European Ariane Espace Programme. Efforts to find substitutes for these programmes concern CRYOSPACE for liquid rocket engines and Societe Europeénne de Propulsion (S.E.P.) for solid motors.

The Japanese space rocket industry currently uses CFC-113 and TCA but expects to phase out the uses by the end of 1995. Latest achievements include the solid rocket booster (SRB) for the H-II launch vehicle which is capable of launching a 2 Ton satellite to Geosynchronous orbit.

11.10 Cleaning of oxygen systems

In January 1994 NATO identified the cleaning of oxygen systems as one of the most difficult challenge facing military and aerospace applications. In Fall 1994, the International Cooperative for Ozone Layer Protection (ICOLP), Aerospace Industry Association (AIA), U.S. EPA, National Aeronautical and Space Administration (NASA) and the U.S. Air Force convened a special workshop on cleaning of oxygen systems without ozone-depleting solvents.

Oxygen systems include: life support systems such as diving, totally encapsulated suits, emergency breathing devices, fire & rescue backpacks, submarine, aircraft, manned spacecraft, and medical applications; propulsion systems such as liquid rocket motors; industrial systems such as chemical production; and other unique systems and customer products such as welding equipment.

Oxygen systems must be kept clean because organic compound contamination, such as hydrocarbon oil, can ignite easily and provide a kindling chain to ignite surrounding materials. Contamination can also consist of particles that could ignite or cause ignition when impacting other parts of the system. Risk is increased by the typical proximity of oxygen systems to very large quantities of fuel materials, and the common necessity of locating oxygen systems in confined spaces with difficult or impossible access and egress (e.g. space ships, submarines, aircraft, and surface ships).

Examples of the challenges presented by these applications include the cleaning of the space shuttle external fuel tank, cleaning of aircraft carrier liquid oxygen plants, cleaning of installed submarine and transport aircraft high pressure oxygen systems, and the gauges and instrumentation associated with each. Examples of devices typically cleaned in these systems include tubing, gauges, regulators, valves, and metering devices. It is usually most effective to clean oxygen equipment at the piece part level in a proper facility. It is more difficult to clean oxygen equipment in aircraft and ship equipment in place with difficult accessibility and temperature extremes. Additional challenges occur in many other industrial oxygen systems such as those used in production and transfer of both gaseous and liquid oxygen, in medical applications, and in welding. Cleaning of equipment used in the oxygen production industry involves unique challenges such as compatibility with aluminum heat exchangers.

Solvents such as non-ozone depleting chlorinated solvents and hydrocarbons often clean satisfactorily, but all have environmental or toxicity concerns, and some have flammability concerns.

Aqueous cleaning options have been successfully developed and implemented for many oxygen system cleaning situations. For example, Lockheed uses aqueous processes in the manufacturing and maintenance of aircraft and missile oxygen systems, the Air Force uses aqueous cleaning for some aircraft oxygen system maintenance, NASA/Kennedy Space Center uses aqueous solutions for cleaning oxygen bulk storage and transfer systems for rocket motors, and the U.S. Navy uses aqueous cleaning processes for cleaning the tubing in oxygen systems on ships and submarines.

Isopropyl alcohol (IPA) is being used by Lufthansa German Airlines to clean the oxygen systems in their commercial aircraft fleet. Sweden has reported using a solvent blend for oxygen system cleaning consisting of 95% ethanol.

Some parts of oxygen systems can be changed to simplify or avoid the necessity of cleaning or they can be adapted to allow aqueous cleaning.

Some oxygen system components still depend on CFC or chlorinated solvent cleaning because current alternatives and substitutes are not technically suitable. In other cases, rigid specifications and requirements may need to be changed from prescriptive to performance standards to allow technically feasible solutions to be used.

This Report includes case studies of successful elimination of ozone-depleting solvents which discuss the evaluation and implementation of materials, alternative technologies, and processes. The following are included in Chapter 11: Allied Signal (evaluation of aqueous saponifiers), AT&T Bell Labs (non-ODS alternatives including no-clean soldering), Beck Electronics (alternative solvents and design of cleaning equipment), Ford Motor Company (no-clean soldering), Hitachi (non-ODS alternatives), Honeywell (non-ODS alternatives), IBM Corporation (no-clean soldering), Japan Industrial Conference on Cleaning (information dissemination), Lockheed Sanders Company (company phaseout efforts), Miljoministeriet (hydrocarbon dry cleaning), Minebea Company (aqueous cleaning of ball bearings), National Semiconductor (company phaseout efforts), Naval Aviation Depot Cherry Point (hand-wipe cleaning), Northern Telecom (company phaseout efforts), Robert Bosch Corporation (aqueous cleaning), Rockwell International (low-residue flux), Seiko Epson Corporation (alternatives to ODSs), Singapore Institute of Standards and Industrial Research (ODS-free certification of businesses), Swedish EPA (country-wide phaseout efforts), Toshiba Corporation (vinyl-copolymer masking agent), U.S. Air Force Aerospace Guidance and Metrology Center (aqueous & non-aqueous alternatives), Vibro-Meter, SA (water-based cleaning).

11.11 Total Equivalent Warming Impact (TEWI)

Total Equivalent Warming Impact (TEWI) provides an important tool in the selection procedure for alternative cleaning and drying technologies. However, TEWI but must not be the only criterion when selecting the cleaning or drying system or technology for a manufacturing process. The Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) has provided a methodology to calculate TEWI for wide range of available systems.

The selection of the best technology to displace CFC-113 or 1,1,1-trichloroethane (methyl chloroform) must be specific to the intended applications and will represent a trade-off or balancing of several key parameters: worker safety (toxicity or flammability concerns), investment, operating costs, energy efficiency and reliability as well as a series of environmental issues; e.g., discharges to water or landfill, local environmental air quality (smog) and global impact (ozone depletion or climate change).

This report has evaluated one of the selection parameters, TEWI, for a number of systems. A summary of the key findings follows.

- Solvent losses from the cleaning equipment are assumed to be potentially lower than assumed in the 1991 study, resulting in lower calculated contributions to TEWI. This reduction in emissions is possible through the adoption of enhanced vapour recovery and improved/novel approaches to materials handling (e.g., freeboard dwell). In some cases, the above technologies can be retrofitted to very modern existing equipment, with results almost comparable to new equipment. However, such equipment will require careful operation and maintenance to sustain low emission rates.

- The no-clean systems used for the manufacture of printed wiring assemblies have the potential for the lowest TEWI. For metal cleaning, chlorocarbon-based systems (e.g., PCE, TCE) have been estimated to have the potentially lowest TEWI.

However, these chlorinated solvent systems may be subject to various national, regional and/or local regulations or emission limits that may severely limit the use of these chemicals for cleaning applications.

- The PFC system studied has the highest TEWI.
- While they use more energy per unit of work (throughput), aqueous, semi-aqueous and alcohol systems generally have been shown to have a lower TEWI than HCFC and HFC-based systems because emissions from aqueous, semi-aqueous, and alcohol systems do not contribute to global warming.
- In the case of HCFC/HFC/PFC-based systems, the direct effect caused by emission of the chemical, represents from 40 percent to over 90 percent of the calculated contribution to potential global warming.

Future study should assess the effects of variations in equipment and practices on TEWI and estimate implementation time for alternative systems in developing countries.

12 Summary of the Report of the Economic Options Committee

12.1 Introduction

12.1.1 The EOC Report describes the transition from developed country ODS phaseout ("Phase 1") to concentration on progressing the developing country phaseout ("Phase 2") under the Montreal Protocol.

12.1.2 Phase 1 is defined in the EOC Report as that part of the implementation process through to the ODS phaseout in the developed countries at the end of 1995. The focus of Phase 1 has been on the urgency of protecting the ozone layer eg establishment of the Protocol; building consensus and institutions; promoting development of ODS alternatives and their use in developed countries. Phase 1 provided examples of the critical importance of individual leadership in securing "lift-off" for the Protocol process. Following the launch of the institutions of the Protocol, the varying adequacy of their performance and of the implementing agencies became increasingly apparent.

12.1.3 Phase 2, in broad terms, is defined as the ODS phaseout in the Article 5(1) countries as of the beginning of 1996 plus the continuing controls on HCFCs and methyl bromide in the developed countries. We are now in the early stages of the transition to Phase 2 with the approaching phaseout in the developed countries and evidence of a review and re-thinking of priorities, mechanisms and resourcing by developed countries. For example,

- some institutional initiatives need to work better;
- the increasing prominence being given to compliance issues eg trade in newly produced ODS misrepresented as "recycled" material; and
- the influence of new people and new perspectives on the evolution of the Protocol process.

12.1.4 The EOC Report develops the transition theme by (1) reminding the reader of the remarkable achievements recorded during Phase 1; (2) identifying and substantiating the scope for improvements in those institutions and processes that are essential to the successful implementation of the Montreal Protocol; (3) identifying and assessing the key concerns regarding the implementation process as it moves into Phase 2; (4) addressing some salient aspects of these concerns; and concludes with general and specific lessons of the Protocol process that might be transferable to the design of other international environmental agreements.

12.1.5 This summary does not follow the chapter sequence of the Report ie each element of the transition theme draws on more than one chapter of the Report.

12.2 Achievements

12.2.1 The achievements realized during Phase 1 have progressed more rapidly, and at lower economic cost, than had been expected at the signing of the Montreal Protocol. Economists have referred to the unexpected achievements of the Protocol given the initial resistance of powerful economic, corporate and regulatory forces to the technical and economic feasibility of its objectives. The ratifications of the Montreal Protocol (1990), the London Amendment (1992), and the Copenhagen Amendment (1994) were highly important and substantial achievements. Yet perhaps even more impressive has been the way scarce talents and resources have been mobilised to forge the progress that has been achieved in ODS reduction.

12.2.2 The EOC Report explores possible explanations for these surprising achievements of the Protocol during Phase 1. This is not a matter of speculative or historical interest; it conditions the EOC's interpretation of the major risks facing the Protocol during the transition to Phase 2.

12.2.3 The success of Phase 1 was not inevitable. The first step required that the stratospheric ozone-depletion problem be identified and credible. To do this, the scientific community had to document both the existence and anthropogenic sources of the problem as well as the seriousness of the potential effects. Second, industry and the research and development community had to be mobilised. Third, the international political and policy-making communities had to negotiate, design and implement the Montreal Protocol; and fourth, public and private enterprises had to implement the new technology. Without credible science neither the industrial nor the political communities could have been mobilised; nor could this have happened without the contribution of the policy-making community to the design of cost-effective policy regimes created the market incentives needed to mobilize industry's resources in support of ODS reduction. Whilst consumer responses to the use of ozone-depleting substances, especially in aerosols, provided an early market incentive to producers, industry's powerful contribution to the achievements of Phase 1 were firmly based on the market incentives provided by the regulatory regimes that were designed to implement the ODS phaseout schedules of the Montreal Protocol.

12.2.4 Companies developed a wide range of technologies ranging from non-ozone depleting chemical substitutes to not-in-kind methods (including product redesign) to replace ODS applications. In non-Article 5(1) countries, the need to phase out ODSs led to both technological and organizational innovation across the industrial spectrum. In some cases the new methods have been profitable in the narrow economic sense as well as being beneficial for the environment. Focused innovation and increased management attention have produced cost-saving and product-improving opportunities. Case studies in the refrigeration and electronics sectors attest to the success of the conversions to non-ozone depleting methods.

12.2.5 Article 5(1) countries are also contributing to the phaseout. Ozone-friendly technologies are being developed and diffused in these countries through the transfer of equipment and expertise by multinational corporations, individual and joint national research programs, industry organizations (such as ICOLP, JICOP, and JEMA), and international government-industry partnerships. The Multilateral Fund, agreed at the London Meeting of the

Parties in 1990, is playing an important role in facilitating the transfer of ozone-friendly technologies to Article 5(1) countries.

12.2.6 This record of achievement is largely the product of an informal network or "community" amongst a broad span of experts (eg industrialists, scientists, technologists, policy-makers, economists, NGOs) with a common interest in the objectives of the Montreal Protocol ie the "Protocol community".

12.3 Improvements are necessary

12.3.1 The achievements of Phase 1 have been impressive, but the "Protocol community" should not relax its efforts during the transition to Phase 2 - there remains much important work to be done. There are obstacles remaining. Some ODSs, such as the pesticide methyl bromide, are not as far along in the replacement process as the ODSs originally controlled under the Protocol. Although ODSs in some critical uses (such as solvents in electronics manufacture) have all but been eliminated, in other industries it is likely that the easier substitutions were undertaken first. Complete elimination of ODSs in all sectors will continue to challenge management, engineering, and production staffs.

12.3.2 A number of policy issues also remain to be resolved. These include: matching the global phaseout schedule of all significant ODSs to the most recent scientific and environmental assessments of the risks those substances pose to the ozone layer; ensuring the adequacy of the Multilateral Fund to fulfil its mandate of covering the incremental costs of the phaseout to Article 5(1) countries; appropriately regulating transitional chemicals such as HCFCs: intelligently managing the stock of already produced ODSs to minimize premature obsolescence of existing ODS-using equipment; and designing and implementing policies that will encourage innovation and productivity growth while meeting the environmental imperative to protect the ozone layer.

12.3.3 Whilst seeking to overcome obstacles and to resolve key policy issues, the "Protocol community" play important roles in bringing expertise to bear on recurrent efforts to weaken the critical underpinnings of the commitment to implement the Montreal Protocol eg (1) the science base; (2) the availability and cost of ODS alternatives; (3) the net benefits of the ODS phaseout; (4) the political commitment to the Article 5(1) countries; (5) the capacity to resolve operational shortcomings eg of non-compliance; inadequate institutional performance; gaps in management controls; public confidence in and political commitment to the Protocol process. In practice, the capacity both to resolve real uncertainties and to provide the advice needed to discriminate between constructive criticism and "de-bunking" efforts lies within the "Protocol community".

12.4 Concerns regarding continued progress

12.4.1 The successful transition from Phase 1 to Phase 2 will require continuing support for the phaseout process in the Article 5(1) countries. Although some Article 5(1) countries have successfully accelerated their phaseout schedules, it is not possible for the Article 5(1) countries, as a whole, to take the full burden of responsibility for their own phaseouts. The preparation of the EOC Report exposed a widely-based concern over whether and to the extent to which the developed countries might reduce their commitments to the Article 5(1) countries during the transition to Phase 2.

12.4.2 The major concerns of the Article 5(1) countries brought to the attention of the EOC were as follows:

- whether political support to stratospheric ozone protection will be sufficient to sustain the transition to Phase 2 and the subsequent phase-out process;
- the adequacy of political and financial support for the institutions of the Montreal Protocol; and
- the extent to which a cooperative approach of industry to the transfer of technology to the Article 5(1) countries can be sustained.

12.4.3 Concern was also expressed over the potential for bilateral assistance to increase relative to multilateral assistance. Whilst bilateral assistance might bring quicker disbursement, concern over cost-effectiveness led to suggestions that bilateral projects should be subject to the same degree of scrutiny as that applied to multilateral projects.

12.4.4 The transition from Phase 1 to Phase 2 has revealed a perceived risk that supplies of ODS and ODS alternatives might not be adequate to meet market demand on terms acceptable to the Article 5(1) countries. The consequences could be unexpectedly large increases in ODS prices and higher than expected adjustment costs during the phase-out process.

12.4.5 Chapter 6 of the Report raises concerns regarding the compatibility of the Protocol with (1) the trade provisions of the GATT/WTO; and (2) the potential for trade restrictions to be imposed on recycled ODS either for reclaiming or redistribution under the Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal. It remains to be seen how the WTO Trade and Environment Committee will review the world trade implications of the Protocol's trade measures, especially with respect to trade in products that are made with but not containing ODSs. The UNEP Ozone Secretariat and the Basel Convention Secretariat are keeping in close contact over these matters. So far, no specific cases of incompatibility between the Montreal Protocol and the Basel Convention have been reported.

12.5 Addressing the concerns of the article 5(1) countries.

12.5.1 Success in responding to these concerns is likely to be variable. The capacity to manage them lies, largely, with the "Protocol community". This capacity cannot be sustained without adequate resourcing. Signals to the effect that the donor countries are re-thinking the extent of their resource commitments to the Protocol process as the transition from Phase 1 to Phase 2 progresses are raising raise concern over the future capacity of the "Protocol community" to help secure the success of Phase 2 of the implementation process.

12.5.2 Concerns over the supplies of ODSs and ODS alternatives during the transition to Phase 2 could be reduced by establishing broadly-based recovery, recycling and banking operations. The work of the EOC indicates that the economic incentives to recycle and reclaim CFCs, and to repair and retrofit CFC-using equipment, would strongly influence the amount of CFCs available to service existing equipment. The adequacy of the current stock of CFCs (including stockpiles and the material contained in functioning equipment) for future service needs will depend on leakage rates, retrofit rates, and recovery rates, which are all variables that are responsive to prices, as well as on the costs of cleaning, storing, and ensuring the quality of the recycled CFCs. With intelligent bank management, it should be possible to avoid shortages over the normal lifetimes of existing CFC-using equipment. The EOC Report describes specific government policies that could increase the effectiveness of recycling and banking operations.

12.5.3 The EOC's review of policy regimes for ODS phaseouts in Chapter 4 highlights the following key findings that could help Article 5(1) countries to increase the efficiency of their phaseout regimes:

- voluntary initiatives are more effective in generating publicity and momentum for ODS phaseouts where there is an aware public group or NGOs capable of monitoring progress;
- most countries opt for some sort of quantitative restrictions (eg quotas) managed through import and, in some cases, production permit or licensing systems;
- permit systems have been used as a relatively simple way of generating efficiency gains during the phaseout; and
- excise taxes have been used to discourage ODS use, reduce "excess profits" generated by rising ODS prices due to regulatory controls, and to raise revenue eg to help finance ODS phaseouts.

12.5.4 The EOC took note of the concerns facing the information-exchange services of the Montreal Protocol institutions during the transition to Phase 2. The EOC takes the view that user demand for these services will continue at a high level. It noted that changing information needs and innovation in information systems will provide opportunities to improve performance. Responses should focus on building consensus regarding (1) the proper role of information exchange services, and (2) the capacity to identify and meet the evolution of user demand in a cost-effective manner. The view of the EOC is that information exchange is an essential element of the "package of inputs" required to achieve ODS reduction.

12.5.5 The supply of information regarding ODSs and the global response to their phaseout is now overwhelming. The capacity to identify, organize, retrieve and use the most pertinent scientific and technical information is a key resource in the ODS phaseout process. The information exchange services provided under the Protocol are well-placed to meet the need for an up-to-date repository and locus for dissemination of the ever-expanding wealth of scientific, technological and organizational information pertinent to the phaseout process. There are three particular areas of information exchange that appear to be highly promising ie

- the community of relevant "experts" from industry, government and academia;
- local or regional networks of those involved in the implementation of the Protocol; and
- "smart" global communication networks enabling the linking of databases via eg INTERNET.

All of these areas are being addressed by the Ozone Action Information Clearinghouse. However, the performance of these programmes has been questioned sufficiently for EOC to suggest that a formal performance evaluation should be undertaken of all information exchange activities carried out by the institutions of the Montreal Protocol and their implementing agencies.

12.6 Transferability

12.6.1 The EOC concluded its Report with an attempt to identify general and specific lessons that might be transferable to the design of other international environmental agreements (IEAs). It addresses the structural design features of the Protocol; performance within these structures is not addressed.

12.6.2 The distinctive aspect of the Montreal Protocol is that it was the first IEA to strike a politically feasible working balance between the scientific, technological and economic factors relevant to the achievement of an explicit global environmental objective. It is argued in Chapter 8 that many of the elements of the Montreal Protocol process might usefully be incorporated in the design of new IEAs. Even so, the selection of the specific elements to transfer must be evaluated with respect to the experience already gained and also have regard to the specific characteristics, needs and constraints of the new IEAs in the making. In this way, steady progress can be made up the "learning curve" that applies to the design of IEAs and hence to more efficient instruments for managing risks to the global environment.

Appendix A

Panel and Options Committee Members
(as of 30 November 1994)

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Andrea Hinwood	Monash University	Australia
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Tom Morehouse	Institute for Defense Analyses	USA
Jose Pons Pons	Spray Quimica C.A.	Venezuela
Sally Rand	Environmental Protection Agency	USA
Gary Taylor	Taylor/Wagner Inc.	Canada
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Methyl Bromide Technical Options Committee

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Paul Cammer	Cammer & Associates	USA
Don Colley	Bovar Inc.	Canada
Brent Davey	Centre for Environmental Mgt.	Australia
Dave Davis	Vulcan Chemicals	USA
James DeAngelis	Commodore Environmental Services	USA
Connie Deford	Dow Chemical	USA
Vinci Felix	DuPont	USA
Howard Greene	University of Akron	USA
Robert Hall	Environmental Protection Agency	USA
Kirk Hummel	Radian Corp.	USA
Chun Wai Lee	Environmental Protection Agency	USA
Karen Metchis	Environmental Protection Agency	USA
Koichi Mizuno	MITI	Japan
Maurice Oubre	Dow Chemical	USA
Kash Ram	Environment Canada	Canada
Rosemary Townsend	Commonwealth EPA	Australia

Inadvertent Losses Sub-Committee

Chairs	**Affiliation**	**Country**
Nick Campbell	ICI Chemicals and Polymers Ltd	UK
Lambert Kuijpers	Technical University Eindhoven	Netherlands

Sub-Committee Members	**Affiliation**	**Country**
Kathi Anderson	DuPont	Canada
Sandip Bhatia	Navin Fluorine Industries	India
Connie Deford	Dow Chemicals (North America)	USA
Kevin Fay	Alliance for Responsible Atmospheric Policy	USA
Jean Lamont	Department of Trade and Industry	UK
Paul Horwitz	Environmental Protection Agency	USA
Hiroshi Kurita	Japanese Association for the Hygiene of Chlorinated Solvents	Japan
Vivian McIntire	Eastman Chemical Company	USA
Wolfgang Scholten	Hoechst AG	Germany
Y Umeki	Mitsui-DuPont	Japan
John Wilkinson	Vulcan Chemicals	USA
Xiao Xu Pei	Shanghai Institute of Organo Fluorine Materials	China

Appendix B

Decisions of the Parties
Relating to the Technology and Economic Assessment Panel

Decision IV/13. Assessment panels

1. To note with appreciation on work done by the Panels for Ozone Scientific Assessment, Environmental Effects Assessment, and Technology and Economic Assessment in their reports of November-December 1991;

2. To request the Technology and Economic Assessment Panel and its Technical and Economic Options Committees to report annually to the Open-ended Working Group of the Parties to the Montreal Protocol the technical progress in reducing the use and emissions of controlled substances and assess the use of alternatives, particularly their direct and indirect global-warming effects;

3. To request the three assessment panels to update their reports and submit them to the Secretariat by 30 November 1994 for consideration by the Open-ended Working Group and by the Seventh Meeting of the Parties to the Montreal Protocol. These assessments should cover all major facets discussed in the 1991 assessments with enhanced emphasis on methyl bromide. The scientific assessment should also include an evaluation of the impact of sub-sonic aircraft on ozone;

4. To encourage the panels to meet once a year to enable the co-chairpersons of the panels to bring to the notice of the meetings of the Parties to the Montreal Protocol, through the Secretariat, any significant developments which, in their opinion, deserve such notice;

Decision IV/23. Methyl bromide

1. To request the Scientific Assessment Panel and the Technology and Economic Assessment Panel to assess the following, in accordance with Article 6 of the Protocol, and to submit their combined report, through the Secretariat, by 30 November 1994 at the latest, to the Seventh Meeting of the Parties:

   (a) Abundance of methyl bromide in the atmosphere and the proportion of anthropogenic emissions within this abundance of methyl bromide and the ozone-depleting potential of methyl bromide;

   (b) Methodologies to control emissions into the atmosphere from the various current uses of methyl bromide and the technical and economic feasibility and the likely results of such controls;

   (c) Availability of chemical and non-chemical substitutes for the various current uses of methyl bromide; their cost-effectiveness; the incremental costs of such substitutes, technological and economic feasibility of substitution for various uses and the benefits to the protection of the ozone layer by such substitution, taking into account the particular social, economic, geographic and agricultural conditions of different regions and, specifically, the developing countries;

2. To request the Open-ended Working Group of the Parties to the Montreal Protocol to consider this report and submit its recommendations to the Seventh Meeting of the Parties in 1995;

Decision IV/25. Essential uses

1. To apply the following criteria and procedure in assessing an essential use for the purposes of control measures in Article 2 of the Protocol:

    (a) That a use of a controlled substance should qualify as "essential" only if:

        (i) It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects); and

        (ii) There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health;

    (b) That production and consumption, if any, of a controlled substance for essential uses should be permitted only if:

        (i) All economically feasible steps have been taken to minimize the essential use and any associated emission of the controlled substance; and

        (ii) The controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substance, also bearing in mind the developing countries' need for controlled substances;

    (c) That production, if any, for essential use, will be in addition to production to supply the basic domestic needs of the Parties operating under paragraph 1 of Article 5 of the Protocol prior to the phase-out of the controlled substance in those countries;

2. To request each of the Parties to nominate, in accordance with the criteria approved in paragraph 1 (a) of the present decision, any use it considers "essential", to the Secretariat at least six months for halons and nine months for other substances prior to each Meeting of the Parties that is to decide on this issue;

3. To request the Technology and Economic Assessment Panel and its Technical and Economic Option Committee to develop, in accordance with the criteria in paragraphs 1 (a) and 1 (b) of the present decision, recommendations on the nominations, after consultations with experts as necessary, regarding:

    (a) The essential use (substance, quantity, quality, expected duration of essential use, duration of production or import necessary to meet such essential use);

(b) Economically feasible use and emission controls for the proposed essential use;

(c) Sources of already produced controlled substances for the proposed essential use (quantity, quality, timing); and

(d) Steps necessary to ensure that alternatives and substitutes are available as soon as possible for the proposed essential use;

4. To request the Technology and Economic Assessment Panel, while making its recommendations to take into account the environmental acceptability, health effects, economic feasibility, availability, and regulatory status of alternatives and substitutes;

5. To request the Technology and Economic Assessment Panel to submit its report, through the Secretariat, at least three months before the Meeting of the Parties in which a decision is to be taken. The subsequent reports will also consider which previously qualified essential uses should no longer qualify as essential;

6. To request the Open-ended Working Group of the Parties to consider the report of the Technology and Economic Assessment Panel and make its recommendations to the Fifth Meeting of the Parties for halons and at the Sixth Meeting for all other substances for which an essential use is proposed;

7. That essential use controls will not be applicable to Parties operating under paragraph 1 of Article 5 of the Protocol until the phase-out dates applicable to those Parties;

Decision IV/30. Hydrochlorofluorocarbons (HCFCs)

1. To request the Technology and Economic Assessment Panel:

(a) To evaluate alternative substances and technologies to the application for HCFCs as refrigerant and as insulation gas in rigid foam;

(b) To identify other applications for HCFCs, if any, where other more environmentally suitable alternatives or technologies are not available; and

(c) To submit its findings to the Open-ended Working Group of the Parties to the Montreal Protocol no later than 31 March 1994;

2. To request the Open-ended Working Group to consider the report of the Technology and Economic Assessment Panel with respect to HCFCs; to consider the possible need for specific provisions for the implementation of the regulation on the applications for HCFCs, taking into account the special circumstances of the Parties operating under paragraph 1 of Article 5 of the Protocol; and to make any appropriate recommendations for consideration by the Parties at their Meeting in 1994 and following subsequent reviews taking place under Article 6 of the Protocol;

3. To ensure that, notwithstanding the new status of HCFCs as controlled substances, the incremental costs to Parties operating under paragraph 1 of Article 5 of the Protocol of making the transition from CFCs to HCFCs consistent with the regulation on the applications for HCFCs will continue to be met by the Fund and to request the Executive Committee to function in the light of this decision;

4. To request the Executive Committee to estimate, on an ongoing basis, the amount of HCFCs required by Parties operating under paragraph 1 of Article 5 of the Protocol and to recommend the methods of meeting such needs in full, simultaneously with the exercise to estimate the amounts of controlled substances needed, as well as to estimate the production available to meet those needs, as requested by the Open-ended Working Group at its seventh meeting.

Decision V/8. Consideration of alternatives

1. That each Party is requested, as far as possible and as appropriate, to give consideration in selecting alternatives and substitutes, bearing in mind, *inter alia*, Article 2F, paragraph 7, of the Copenhagen Amendment regarding hydrochlorofluorocarbons, to:

    (a) Environmental aspects;

    (b) Human health and safety aspects;

    (c) The technical feasibility, the commercial availability and performance;

    (d) Economic aspects, including cost comparisons among different technology options taking into account:

        (i) All interim steps leading to final ODS elimination;

        (ii) Social costs;

        (iii) Dislocation costs, etc.

    (e) Country-specific circumstances and due local expertise;

2. To note that the Executive Committee is taking the above considerations into account as far as information is available;

3. To request the Technology and Economic Assessment Panel and its Technical Options Committees in the context of finalizing its report, to provide information on which alternatives and substitutes best satisfied the above considerations, and to update this information on an annual basis;

Decision V/18. Timetable for the submission and consideration of essential use nominations

1. To request the Parties to submit their nominations for each production and consumption exemption for substances other than halon for 1996 in accordance with Decision IV/25, with the presumption that the Meeting of the Parties will be held on 1 September;

2. To modify the timetables in Decision IV/25 for nominations for halon production and consumption exemptions for 1995 and subsequent years, and for nominations for production and consumption exemptions for substances other than halon for 1997 and subsequent years as follows: to set 1 January of each year as the last date for nominations for decisions taken in that year for any subsequent year;

3. To request the Technology and Economic Assessment Panel and its relevant Technical Options Committees to develop recommendations on the nominations and submit their report through the Secretariat by 31 March of that year;

4. To request the Open-ended Working Group of the Parties to consider the report of the Technology and Economic Assessment Panel and make its recommendations to the subsequent meeting of the Parties;

5. To request the Technology and Economic Assessment Panel to assemble and distribute a handbook on essential uses nominations including copies of relevant decisions, nomination instructions, summaries of past recommendations, and copies of nominations to illustrate possible formats and levels of technical detail;

Decision V/19. Control measures to be applicable to Parties operating under paragraph 1 of Article 5 of the Protocol with respect to the controlled substance in Group I of Annex C, Group II of Annex C, and Annex E

1. To request the Scientific Assessment Panel and the Technology and Economic Assessment Panel in collaboration with the Secretariat and the Executive Committee to assess the following, in accordance with Article 6 and taking into account the report required by decision V/11 of the Protocol and to submit their combined report, through the Secretariat, by 30 November 1994 at the latest, to the Seventh Meeting of the Parties:

   (a) What base year, initial levels, control schedules and phase-out date for consumption of controlled substances in Group I of Annex C are feasible for application to Parties operating under paragraph 1 of Article 5 of the Protocol;

   (b) What base year, initial levels and control schedules for consumption and production of the controlled substances in Group II of Annex C are feasible for application to Parties operating under paragraph 1 of Article 5 of the Protocol;

   (c) What base year, initial levels and control schedules for consumption and production of the controlled substances in Annex E are feasible for application to Parties operating under paragraph 1 of Article 5 of the Protocol;

2. To request the Open-ended Working Group of the Parties to the Montreal Protocol to consider the combined report of the two Assessment Panels and submit its recommendation to the Seventh Meeting of the Parties, in 1995;

Decision V/20. Extension of application of trade measures under Article 4 to controlled substances listed in Group I Annex C and in Annex E

1. To request the Technology and Economic Assessment Panel to assess the feasibility and implications of extending the application of trade measures under Article 4 of the Protocol to trade in the controlled substances listed in Group I of Annex C and in Annex E and report through the Secretariat by 30 November 1994 at the latest to the Open-ended Working Group;

2. To request the Open-ended Working Group to make recommendations on the subject, as appropriate, with a view to their consideration by the Seventh Meeting of the Parties, in 1995;

Decision VI/10. Use of controlled substances as process agents

Taking into account:

That some Parties may have interpreted use of controlled substances in some applications where they are used as process agents as feedstock application;

That other Parties have interpreted similar applications as use and thereby subject to phase-out;

That the Technology and Economic Assessment Panel has been unable to recommend exemption, under the essential use criteria, to Parties submitting applications of such uses nominated in 1994; and

The pressing requirement for elaboration of the issue and the need for appropriate action by all Parties;

1. To request the Technology and Economic Assessment Panel:

   (a) To identify uses of controlled substances as chemical process agents;

   (b) To estimate emissions of controlled substances when used as chemical process agents and the ultimate fate of such emissions and to evaluate emissions associated with the different control technologies and other process conditions under which chemical process agents are used;

   (c) To evaluate alternative process agents or technologies or products available to replace controlled substances in such uses; and

   (d) To submit its findings to the Open-ended Working Group of the Parties to the Montreal Protocol not later than March 1995, and to request the Open-ended Working Group to formulate recommendations, if any, for the consideration of the Parties at their Seventh Meeting;

2. That Parties, for an interim period of 1996 only, treat chemical process agents in a manner similar to feedstock, as recommended by the Technology and Economic Assessment Panel, and take a final decision on such treatment at their Seventh Meeting;

Decision VI/11. Clarification of "quarantine" and "pre-Shipment" applications for control of methyl bromide

1. Recognizing the need for non-Article 5 Parties to have, before 1 January 1995, common definitions of "quarantine" and "pre-shipment" applications for methyl bromide, for purposes of implementing Article 2H of the Montreal Protocol, and that non-Article 5 Parties have agreed on the following:

(a) Quarantine applications, with respect to methyl bromide, are applications to prevent the introduction, establishment and/or spread of quarantine pests (including diseases), or to ensure their official control, where:

(i) Official control is that performed by, or authorized by a national plant, animal or environmental protection, or health authority;

(ii) Quarantine pests are pests of potential importance to the areas endangered thereby and not yet present there, or present but not widely distributed and being officially controlled;

(b) Pre-shipment applications are those treatments applied directly preceding and in relation to export, to meet the phytosanitary or sanitary requirements of the importing country or existing phytosanitary or sanitary requirements of the exporting country;

(c) In applying these definitions, non-Article 5 countries are urged to refrain from use of methyl bromide and to use non-ozone-depleting technologies wherever possible. Where methyl bromide is used, Parties are urged to minimize emissions and use of methyl bromide through containment and recovery and recycling methodologies to the extent possible;

2. Acknowledging that Article 5 Parties have agreed to identify the following:

(a) That definitions relating to pre-shipment applications affect Article 5 countries and that new non-tariff barriers to trade should be avoided;

(b) That the Article 5 countries still need to have more consultations and further approaches to the quarantine and pre-shipment application definitions related to methyl bromide;

(c) That the Food and Agricultural Organization of the United Nations should play a fundamental role in the establishment of common definitions concerning quarantine and pre-shipment applications related to methyl bromide use;

(d) That it is anticipated that the use of methyl bromide by Article 5 countries may increase in the forthcoming years;

(e) That adequate resources from the Multilateral Fund for the Implementation of the Montreal Protocol and other sources are needed to facilitate the transfer of non-ozone-depleting technologies for quarantine and pre-shipment applications related to methyl bromide to the Article 5 countries;

3. Further recognizing that containment, recovery and recycling methodologies relating to methyl bromide should be given a wider application among all Parties;

4. To request the open-ended working group of the Parties at its eleventh and twelfth meetings;

(a) To further study the most suitable definition for "quarantine" and"pre-shipment" applications relating to methyl bromide use, taking into consideration:

(i) The Methyl Bromide Technical Options Committee report;

(ii) The Methyl Bromide Scientific Assessment Report;

(iii) The FAO guidelines on Pests Risk Analysis; and,

(iv) The development of lists of injurious pests;

(b) To consider jointly the definitions issues along with the methyl bromide issues contained in Decision VI/13;

(c) To provide the necessary elements to be included for a decision of the Seventh Meeting of the Parties to the Montreal Protocol on all the above issues;

Decision VI/13. Assessment panels

To request the Panels, as an inclusion in their ongoing work, to evaluate, without prejudice to Article 5 of the Montreal Protocol, the technical and economic feasibility, and the environmental, scientific, and economic implications for non-Article 5 countries, as well as, Article 5 countries, bearing in mind Article 5, paragraph 1 bis, of the Copenhagen Amendment, of:

(a) The alternative to hydrochlorofluorocarbons in so doing, the Technology and Economic Assessment Panel is requested to consider the ozone-depleting substance substitution potential of not-in-kind alternatives, in-kind alternatives, and alternative technologies. In assessing this matter, the Technology and Economic Assessment Panel should consider how available alternative compare with hydrochlorofluorocarbons with respect to such factors as energy efficiency, total global warming impact, potential flammability, and toxicity, and the potential impacts on the effective use and phase-out of chlorofluorocarbons and halons; in time for consideration by the Open-ended Working Group at its Eleventh Meeting;

(b) Alternatives to methyl bromide, in time for consideration by the Open-ended Working Group at its eleventh meeting;

In considering these matters, the Scientific Assessment Panel shall consider, if possible, atmospheric chlorine and bromine loadings and their impact on ozone depletion. The Technology and Economic Assessment Panel and Scientific Assessment Panel evaluations shall be solely for the purpose of discussions by the Parties and shall in no way be construed as recommendations for action.

Decision VI/19. Trade in previously used ozone-depleting substances

1. To reaffirm the Parties' intent embodied in decision IV/24;

2. To restate that only used controlled substances may be excluded from the calculated level of consumption of countries importing or exporting such substances;

3. To note further that, as required by decision IV/24, such exclusions from a Party's calculated level of consumption is made contingent on reporting of such imports and exports to the Secretariat and Parties should make their best efforts to report this information in a timely manner;

4. To request all Parties with reclamation facilities to submit to the Secretariat prior to the Seventh Meeting of the Parties and on an annual basis thereafter a list of the reclamation facilities and their capacities available in their countries;

5. To request all Parties that export previously used substances to take, where appropriate, steps to ensure that such substances are labelled correctly and are of the nature claimed and to report any related activities through the Secretariat to the seventh meeting of the Parties;

6. To request such exporting Parties to make best efforts to require their companies to include in documentation accompanying such exports, the name of the source firm of the used controlled substance and whether it was recovered, recycled or reclaimed and any further information available to allow for verification of the nature of the substance;

7. To request the Ozone Secretariat, drawing on the experience of the Technology and Economic Assessment Panel and the Parties, to study and report on trade in used/recycled/reclaimed ozone-depleting substances, taking particular account of Parties' experience in the control of such trade and the concerns and interests of all Parties that have facilities for the production of ozone-depleting substances, in time for the issues to be considered by the Open-ended Working Group at its twelfth meeting;

Appendix C

Global Warming Issues

Based on total emissions, the major greenhouse gases are carbon dioxide (CO_2) and methane (CH_4). However, a substantial contribution is made in the aggregate by other gases including chlorofluorocarbons (CFCs), halons, and other halocarbons. These minor or trace gases are important for two reasons. First, although these gases are currently emitted in smaller quantities than CO_2 and CH_4, their effectiveness in influencing climate tends to be greater. Second, while individual use of these gases may add little to the overall burden, the rising concentration of greenhouse gases in the atmosphere cannot be controlled without addressing the aggregate effect of the trace gases.

As the transition away from the ozone-depleting compounds proceeds, a growing concern is that this shift does not also result in a significant rise in contributions to global warming due to an increased reliance on substitutes that are strong greenhouse gases. Alternatives identified by the Technology and Economic Assessment Panel (TEAP) and its Technical Options Committees (TOCs) to date have varying potential to contribute to global warming. Their contribution depends on many factors including radiative properties and persistence in the atmosphere.

This appendix describes the context of the climate change problem and the general properties of greenhouse gases.

The Nature of the Global Warming Problem

The Earth's stable average temperature is maintained by a radiative balance in which the amount of energy absorbed from the sun is equal to the amount of energy radiated back into space by the Earth and atmosphere. If a factor is introduced into the atmosphere that changes this balance, the climate must warm or cool until the radiative fluxes are equal and the balance is restored. A change of this kind is known as a change in radiative forcing (or warming commitment). Radiative forcing, expressed in watts per square meter (W/m^2), is a measure of the downward radiation flux received by the climate system. Concerns about global warming stem from observed increases in the concentrations of certain gases that may be able to alter the climate by causing an increase in radiative forcing.

A characteristic that these gases share is that they absorb radiation in the infrared (or thermal) part of the electromagnetic spectrum. Most of the energy that the Earth receives from the sun is in the form of shortwave radiation in the visible and ultraviolet parts of the spectrum. The energy emitted from the Earth to space is in the form of longwave radiation in the infrared part of the spectrum. These gases absorb some of the outgoing infrared (or thermal) radiation and re-emit it both up into space and back down to the Earth. The net result is a decrease in the heat radiation escaping to space and an increase in the heat radiation falling to the Earth (an increase in radiative forcing). Because this process tends to concentrate heat in the troposphere, it is known as the greenhouse effect. The gases responsible for the greenhouse effect are known as greenhouse gases. Greenhouse gases include carbon dioxide, methane, and nitrous oxide, as well as chlorofluorocarbons (CFCs) and some CFC substitutes.

Properties of Greenhouse Gases

All organic compounds that can volatilize into the atmosphere share the property that they absorb energy in the infrared portion of the electromagnetic spectrum. However, these gases do not all absorb infrared radiation equally well, and thus some have greater impacts than others on global warming. The following factors determine the global warming impact of emissions of a particular gas:

- Atmospheric lifetime. Various physical and chemical processes tend to remove and break down chemicals in the atmosphere. Atmospheric lifetime is a measure of how long a gas stays in the atmosphere before it is removed by these processes.[1] The lifetimes of the greenhouse gases are determined by their sources and sinks in the oceans, atmosphere, and biosphere. In general, the most effective greenhouse gases are those with long lifetimes since the impact of long-lived gases is more persistent than the impact of short-lived gases. In some cases this persistence may be cause for concern. With very-long-lived gases it may take thousands of years for concentrations to decline significantly after emissions have stopped. Thus, the impacts these emissions have are essentially irreversible.

- Molecular weight. Emissions are typically measured according to their mass (in kilograms). However, the increase in atmospheric concentration (by volume) resulting from an emission is proportional to the number of molecules in the emission, not the total mass of the emission. The number of molecules in an emission of a given mass is inversely proportional to the molecular weight of the gas emitted. As a result, the molecular weight is needed to determine the increase in concentration resulting from an emission of a given mass. The lower the molecular weight of the gas, the greater the increase in concentration resulting from a given emission.

- Radiative forcing per molecule. This is a measure of the effectiveness of the gas at absorbing infrared radiation emitted by the Earth. It is proportional to the increase in radiative forcing resulting from a given increase in concentration.

Of these factors, only molecular weight is an irreducible characteristic of a gas. Atmospheric lifetime depends on other characteristics such as solubility in water, rates of reaction with other components of the atmosphere, and susceptibility to photolysis. Radiative forcing per molecule depends on a number of characteristics that are relevant to greenhouse gas behaviour. These include the following:

- Integrated infrared band strength. Each kind of molecule absorbs energy at a unique set of wavelengths. The wavelengths at which a molecule absorbs

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[1] Atmospheric lifetimes are commonly modeled as e-folding lifetimes. This means that the concentration of a gas is assumed to decay exponentially. Concentration through time is given by the following equation:

$$C_t = C_0 e^{-\frac{t}{L}}$$

where C_t is the concentration at time t, C_0 is the initial concentration, and L is the atmospheric life of the gas. If the initial concentration of a gas is 1 ppb, its concentration after one lifetime is 1/e (about 0.37) ppb. After two lifetimes the concentration is $1/e^2$ (about 0.14) ppb. In theory this means that the concentration is never truly zero. However, after a few lifetimes it does become vanishingly small.

energy are in patterns of contiguous regions in the electromagnetic spectrum which are referred to as absorption bands. A molecule's absorption bands together make up its absorption spectrum. The strength of the gas's infrared absorption spectrum is a measure of how well molecules of the gas absorb radiation at their characteristic wavelengths (i.e., the stronger the absorption band, the more energy that is absorbed by the molecule).

- Location of infrared absorption bands. The location of the gas's infrared absorption bands is important for two reasons: First, the energy radiated from the earth is not evenly distributed across the infrared spectrum. More energy is radiated at some wavelengths than at others. Molecules with absorption bands at wavelengths of high infrared radiation will tend to be more effective greenhouse gases than molecules with absorption bands at wavelengths of low infrared radiation. Second, the impact of a greenhouse gas may be reduced if its absorption bands overlap with those of other gases present in the atmosphere in significant quantities. For example, if a gas has absorption bands that overlap with those of an abundant greenhouse gas like carbon dioxide, the relative impact of the gas on radiative forcing is reduced since much of the energy at these wavelengths is already absorbed.

- Initial concentration of the gas. If the initial atmospheric concentration of a gas is high enough so that a significant portion of the energy at relevant wavelengths is already absorbed, the impact of additional increases in concentration is reduced. This effect is significant for carbon dioxide. It is not significant for CFCs and CFC substitutes since they are present in much smaller quantities than carbon dioxide. Radiative forcing scales linearly with concentration for these chemicals.

A useful index for comparing emissions that incorporates all of these factors is the Global Warming Potential (GWP). The GWP depends on the position and strength of the absorption bands of the gas, its lifetime in the atmosphere, its molecular weight, and the time period over which the climate effects are of concern. Specifically, the GWP is defined as the time-integrated change in radiative forcing resulting from a kilogram of emissions of a given chemical relative to the time-integrated change in radiative forcing resulting from a kilogram of emissions of a reference gas, typically carbon dioxide.[2]

Because different gases have different lifetimes, the period of integration has an important impact on relative GWPs. This point is illustrated by the example of two different gases, each with an initial concentration of 1 ppb. If the lifetime of the first gas is 10 years, its concentration will be $1/e^{10}$ (0.00005) ppb after 100 years (ten lifetimes). A 100-year GWP captures the entire impact of this gas since the concentration of the gas is effectively zero at the end of the period of integration, and it can no longer influence radiative forcing. If the lifetime of the second gas is 100 years, its concentration will be 1/e (about 0.37) ppb after 100 years (one lifetime). A 100-year GWP does not capture the entire impact of this gas since the gas is still present in significant quantities at the end of the period of integration, and it still affects radiative forcing. If the period of integration were lengthened, the ratio of GWPs between the long-lived and the short-lived gases would increase because the value of the integral in the numerator would increase, while the value of the integral in the denominator would remain the same.

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[2] Climate Change: The IPCC Scientific Assessment. Intergovernmental Panel on Climate Change. 1990.

Properties of Ozone-Depleting Substances (ODSs) and ODS Substitutes

Table # presents atmospheric lifetime, molecular weight, integrated infrared band strength and GWPs for a number of class I and II chemicals, and their substitutes. Although there is overlap between categories (with the highest GWP substances in a generally lower category exceeding the GWP of the lowest GWP substances in a generally higher category), in general the PFCs have the highest GWPs among ODS substitutes. Hydrofluorocarbons (HFCs) are next, followed by hydrochlorofluorocarbons (HCFCs), which have generally lower GWPs. Perfluorinated carbons (PFCs) have high GWPs because of their high integrated band strengths and their extremely long atmospheric lifetimes. HCFCs generally have low GWPs because of their short atmospheric lifetimes. HFCs typically fall in the middle because of strong integrated band strengths and moderate atmospheric lifetimes. However, some HFCs have substantially higher GWPs than others. For example, HFC-152a has a 1.5 year atmospheric lifetime and a GWP of 44 for the 500-year time horizon; while HFC-23 has a 250 year atmospheric lifetime and a GWP of 9900 for the 500-year time horizon. In examining this table the following issues should be considered:

- Although the GWPs of ODSs and ODS substitutes may be thousands of times the GWP of the reference gas, carbon dioxide, this is offset by the fact that emissions of these compounds are orders of magnitude smaller than emissions of carbon dioxide.[3]
- If the lifetime of a chemical is short compared to the lifetime of the reference gas, the GWP of the chemical declines as the period of integration increases. If the lifetime of the chemical is long compared to the lifetime of the reference gas, the GWP of the chemical rises as the period of integration increases.[4]
- In practice a high GWP does not necessarily mean a large impact on global warming. If chemicals are never emitted they cannot cause a direct contribution to global warming even if they have high GWPs. For example, if good service practices are in place, emissions from hermetically sealed household refrigerators are very small. If the material is recovered for recycling or destruction after the useful life of the equipment, the refrigerant is never released to affect the atmosphere. In contrast, mobile air conditioners tend to be leaky. Substitutes used in this end use are more likely to be released to the atmosphere and, thus, impact global warming.

Indirect Effects from Changes in Energy Efficiency

In addition to direct and indirect atmospheric effects, ODS substitutes may also have indirect energy effects that can influence global warming. Use of alternative chemicals may change the energy efficiency of equipment and products currently using CFCs. Because most energy is derived from burning fossil fuels, changes in energy efficiency may result in changes in carbon dioxide, nitrous oxide, and methane emissions, which will impact radiative forcing and global warming. The two major end use categories in which the use of alternatives can impact the energy efficiency of equipment or products are refrigeration and air conditioning applications and foam insulation applications.

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[3] This does not account for the indirect atmospheric effect of CFC emissions on radiative forcing. CFCs play a role in the depletion of stratospheric ozone, which is itself a radiatively active gas. Ozone depletion may reduce the net increase in radiative forcing that would otherwise occur as a result of CFC emissions. This indirect effect does not apply to HFC and PFC emissions, which are not ozone depleting.

[4] Because carbon dioxide is removed from the atmosphere through complex processes that cannot be modeled as simple exponential decay, this relationship is not always monotonic.

The Total Equivalent Warming Impact (TEWI) approach calculates the combined global warming influence of the emissions of substances that are greenhouse gasses and the energy used to manufacture and operate equipment using those substances over the useful life of that equipment.

Table 1-#: Atmospheric Lifetime or Response Time and Global Warming Potentials (GWP) (mass basis), referenced to the Absolute GWP for the adopted carbon cycle model CO_2 decay response and future CO_2 atmospheric concentrations held constant at current levels. Only direct effects are considered.[5]

Species	**Atmospheric Lifetime**	**GWP - 20 Years Time Horizon**	**GWP- 100 years Time Horizon**	**GWP- 500 years Time Horizon**
Class I				
CFC-11	50 (+/- 5)	5000	4000	1400
CFC-12	102	7900	8500	4200
CFC-13	640	8100	11700	13600
CFC-113	85	5000	5000	2300
CFC-114	300	6900	9300	8300
CFC-115	1700	6200	9300	13000
CCl4	42	2000	1400	500
Halon 1301	65	6200	110	35
CH_3Br	1.3	NA	NA	NA
Methyl chloroform	5.4 (+/1 0.4)	360	5600	2200
Class II				
HCFC-22	13.3	4300	1700	520
HCFC-123	1.4	300	93	29
HCFC-124	5.9	1500	480	150
HCFC-141b	9.4	1800	630	200
HCFC-142b	19.5	4200	2000	630
HCFC-225ca	2.5	550	170	52
HCFC-225cb	6.6	1700	530	170

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[5] The large ozone depletions observed in the lower stratosphere are believed to influence temperatures near the tropopause. This implies that in addition to the *direct* greenhouse warming of ozone destroying gases there is an *indirect* cooling effect that is significant for estimating the GWPs. Please refer to the *Scientific Assessment of Ozone Depletion: 1994* discussion of the Net Global Warming Potentials.

Table 1-# (continued): Atmospheric Lifetime or Response Time and Global Warming Potentials (GWP) (mass basis), referenced to the Absolute GWP for the adopted carbon cycle model CO_2 decay response and future CO_2 atmospheric concentrations held constant at current levels. Only direct effects are considered.[6] (Source: Science Assessment Panel, *Scientific Assessment of Ozone Depletion: 1994*).

Species	**Atmospheric Lifetime**	**GWP - 20 Years Time Horizon**	**GWP- 100 years Time Horizon**	**GWP- 500 years Time Horizon**
Other				
HFC-23	250	9200	12100	9900
HFC-32	6	1800	580	180
HFC-125	36	4800	3200	1100
HFC-134	11.9	3100	1200	370
HFC-134a	14	3300	1300	420
HFC-143	3.5	950	290	90
HFC-143a	55	5200	4400	1600
HFC-152a	1.5	460	140	44
HFC-227ea	41	4500	3300	1100
HFC-236fa	250	6100	8000	6600
HFC-245ca	7	1900	610	190
HFC-43-10mee	20.8	3300	1600	520
Methylene chloride	0.41	28	9	3
SF_6	3200	16500	24900	36500
CF_4	50000	4100	6300	9800
C_2F_6	10000	8200	12500	19100
$c\text{-}C_4F_8$	3200	6000	9100	13300
C_6F_{14}	3200	4500	6800	9900

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[6] The large ozone depletions observed in the lower stratosphere are believed to influence temperatures near the tropopause. This implies that in addition to the *direct* greenhouse warming of ozone destroying gases there is an *indirect* cooling effect that is significant for estimating the GWPs. Please refer to the *Scientific Assessment of Ozone Depletion: 1994* discussion of the Net Global Warming Potentials.

Appendix D

Glossary

AC	Air Conditioning.
Acute toxicity	The short-term toxicity of a product in a single dose. Can be divided into oral, cutaneous, and respiratory toxicities.
Adsorption	The taking up of some substances at the surface of specific materials through formation of physiochemical bonds. Not to be confused with absorption.
AEL	Average Exposure Limit.
Aerosol Spray	A means of atomizing liquids by propelling them from a pressurized container through a suitable valve by either a liquified or pressurized gas.
AFEAS	Alternative Fluorocarbon Environmental Acceptability Study.
Alcohols	A series of hydrocarbon derivatives with at least one hydrogen atom replaced by an -OH group. The simplest alcohols (methanol, ethanol, n-propanol, and isopropanol) are good solvents for some organic soils, notably rosin, but are flammable and can form explosive mixtures with air. The use of flammable solvents requires caution and well-designed equipment.
Anaphylaxis	An acute life threatening allergic reaction.
Angioplasty	A method of mechanically re-establishing blood flow catheterization through a narrowed arteries.
Anti-inflammatory Agent	A medicine (usually inhaled) which is taken regularly to reduce airway inflammation and thereby prevent asthma attacks.
Anthelminthic agent	An agent to kill parasitic worms.
Aqueous cleaning	Cleaning with water to which suitable detergents, saponifiers, or other additives may be added.
Article 5(1)	Countries classified by the United Nations as developing and classified by the Ozone Secretariat as consuming less than 0.3 kilograms per capita of ozone-depleting substances and Party to the Montreal Protocol.

Azeotrope	A mixture of chemicals is an azeotrope if the vapour composition is identical to that of the liquid phase and evaporates at one certain temperature and pressure (no glides). This means that the distillate of an azeotrope is theoretically identical to the solvents from which it is distilled. In practice, the presence of contaminants in the solvent may upset the azeotrope.
Biodegradable	Products are classified as biodegradable if they can be easily broken down or digested by living organisms.
Blends	A mixture of substances to provide specific performance characteristics. Refrigeration blends are matched to the components and design temperature (evaporation and condensation at certain temperatures and pressures, with a varying temperature glide).
BOD	Biochemical oxygen demand, a measure of the biodegradability of wastewater.
Bronchodilator	A medicine taken to relieve the symptoms of asthma or chronic obstructive pulmonary disease (COPD) and which works by reducing or reversing airway narrowing. There are 3 main types: (a) Beta agonist, which are sympathetic amines which stimulate beta adrenoreceptors in the airway wall causing (among other things) relaxation of bronchial smooth muscle. (b) Anti cholinergic agents, which work by inhibiting airway narrowing produced by the action of the vogus nerve on airway muscle. (c) Theophyllines, alternative airway openers which work by relaxing bronchial wall muscle (can only be taken in tablet or injection form).
Carbon tetrachloride	A chlorocarbon solvent with an ODP of approximately or CTC 1.1 (CCl_4. It is also considered toxic and a probable human carcinogen (classified as a B2 carcinogen by US EPA). Its use is strictly regulated in most countries and it is used primarily as a feedstock material for the production of other chemicals.
CEIT	Countries with Economies In Transition.
CFC	Chlorofluorocarbon.
CFC-11	Trichlorofluoromethane ($CFCl_3$).
CFC-12	Dichlorodifluoromethan (CF_2Cl_2).
CFC-113	Trichlorotrifluoroethane ($C_2F_3Cl_3$.

CFC-113a	An isomer of CFC-113; 1,1,1-trichloro-2,2,2-trifluoroethane.
CFC-114	Dichlorotetrafluoroethane (CF_2ClCF_2Cl).
CFC-115	Monochloropentafluoroethane (CF_2ClCF_3).
CHC	Chlorinated Hydrocarbon.
Chelation	Chelation is the solubilization of a metal salt by forming a chemical complex or sequestering. One way of doing this is with ethylenediaminetetraacetic acid (EDTA) salts which have a multidentate spiral ligand form that can surround metallic and other ions.
Chlorocarbon	An organic substance composed of chlorine and carbon, e.g., carbon tetrachloride.
Chlorofluorocarbon	An organic substance composed of chlorine, fluorine, and carbon atoms, usually characterized by high stability contributing to a high ODP.
Chronic toxicity	The toxicity of a substance encountered repeatedly over a period of time. Chronic means persisting over a long period of time. Chronic toxicity can often take many years to determine.
CIS	Commonwealth of Independent States.
CMA	Chemical Manufacturers Association.
COD	Chemical oxygen demand.
Compressed gas	A high pressure propellant that will behave as a gas inside the aerosol.
Conformal coating	A protective material applied in a thin, uniform layer to surfaces of an electronic assembly.
Controlled atmosphere soldering	A soldering process done in a relatively oxygen-free atmosphere. The process greatly reduces oxidation of the solder, so that less flux is required, thereby reducing or eliminating the need for cleaning.
COPD	Chronic obstructive pulmonary disease- also know as chronic bronchitis and emphysema or chronic airflow limitation, a largely irreversible condition characterized by narrowing of the airways and damage to the air sacs of the lung and usually due to tobacco smoking.
CTC	Carbon tetrachloride. A chlorocarbon solvent and chemical feedstock with ODP of approximately 1.1.

Defluxing	The removal of flux residues after a soldering operation. Defluxing is a part of most high-reliability electronics production.
Detergent	A product designed to render soils (e.g., oils and greases) soluble in water, usually made from synthetic surfactants.
Dichloromethane	A chlorocarbon solvent used extensively for metal cleaning. Also known as methylene chloride.
Dispersive use	Use in which a chemical takes part in a process from which it can be recovered unchanged.
DME	Di Methyl Ether.
DPI	Dry Powder Inhaler.
Dry cleaning	A common term for cleaning garments in organic solvents, as opposed to water.
Dry film	A photoresist or photoimageable solder mask applied to printed circuits by lamination.
Durables	Dry commodities which typically are easily storable for long periods (eg cereal grain, timber).
EAP	Effects Assessment Panel.
EC	European Community.
EO	Ethylene oxide.
100% EO	Commercial grade ethylene oxide without dilution.
EOC	Economic Options Committee.
EPA	U.S. Environmental Protection Agency.
Excipient	An inert material used in the pharmaceutical industry as a binder in tablets.
ExCom	Executive Committee of the Multilateral Fund of the Montreal Protocol.
EU	European Union.
FAO	Food and Agriculture Organization of the United Nations.
Fatty acids	The principal part of many vegetable and animal oils and greases. Also known as carboxylic acids, which embrace a wider definition. These are common contaminants which use solvents for their removal. They are also used to activate fluxes.

Flux	A chemical employed in the soldering process to facilitate the production of a solder joint. It is usually a liquid or solid material, frequently based on rosin (colophony).
FO	Formaldehyde.
GATT	General Agreement on Tariffs and Trade.
Greenhouse effect	A thermodynamic effect whereby energy absorbed at the earth's surface and normally radiated back out to space in the form of long-wave infrared radiation, is retained due to gases in the atmosphere, causing a rise in global temperature. CFCs that cause ozone depletion are "greenhouse gases."
GWP	Global Warming Potential.
Halocarbon	Any organic substance where at least one hydrogen atom in the hydrocarbon molecule has been replaced by a halogen atom (fluorine, chlorine, bromine or iodine).
Halons	Substances used as fire-extinguishing agents and having high ODPs.
HAP	Hydrocarbon Aerosol Propellant.
HBFC	Hydrobromofluorocarbon.
HCFC	Hydrochlorofluorocarbon.
HCFC-21	Dichlorofluoromethane.
HCFC-22	Chlorodifuoromethane (CF_2HCl).
HCFC-123	Dichlorotrifluoroethan (CF_3CHCl_2).
HCFC-124	Monochlorotetrafluoroethane (CF_3CHFCl).
HCFC-141b	Dichlorofluoroethan (CH_3CFCl_2).
HCFC-142b	Monochlorodifluoroethane (CH_3CF_2Cl).
HCFC-225ca	Dichloropentafluoropropane ($CF_3CF_2CHCl_2$.
HCFC-225cb	Dichloropentafluoropropane (CF_2ClCF_2CHFCl.
HCS	Hydrocarbon/surfactant (intra).
HFC	Hydrofluorocarbon.
HFC-125	Pentafluoroethane (CHF_2CF_3).
HFC-134A	Tetrafluoroethane (CH_2FCF_3).
HFC-143A	Trifluoroethane (CH_3CF_3).

HFC-152A	Difluoroethane (CH_3CF_2H).
Hybrid circuits	Electronic circuits, with or without integral passive components, which are formed by the application of conductive and resistive patterns to a vitreous or ceramic substrate.
Hydrocarbon propellant	An organic substance composed only of hydrogen and carbon. Gaseous or volatilized hydrocarbons are flammable.
Hydrocarbon derivative	A hydrocarbon whose molecule has been modified by adding atoms other than hydrogen and carbon, e.g., alcohols.
Hydrocarbon/surfactant	A mixture of low-volatility hydrocarbon solvents with surfactants, allowing the use of a two-phase cleaning process. The first phase is solvent cleaning in the blend and the second phase is water washing and rinsing to remove the residues of the blend and any other water-soluble soils. The surfactant ensures the water-solubility of the otherw[illegible] insoluble hydrocarbon. Sometimes called semi-aqu[illegible]us solvents.
Hydrochlorocarbon	An organic substance composed of hydrogen, chlorine, and carbon, e.g., trichloroethylene.
Hydrochlorofluorocarbon	An organic substance composed of hydrogen, chlorine, fluorine, and carbon atoms. These chemicals are less stable than CFCs, thereby having generally lower ODPs, usually abbreviated as HCFC.
H-1301	CF_3Br
H-1211	CF_2ClBr
H-1202	CF_2Br_2
H-2402	CF_2BrCF_2Br
H-1201	CF_2HBr
H-2401	CF_3CHFBr
H-2311	$CF_3CHClBr$
IARC	International Agency for Research on Cancer.
ICOLP	International Cooperative for Ozone Layer Protection.
Infra-red soldering	A method of reflow soldering where the solder and the parts being joined are heated by the incidence of infra-red radiation in air, in an inert gas, or in a reactive atmosphere.
IPCC	Intergovernmental Panel on Climate Change.
IPR	Intellectual Property Rights.

Isobutane	Hydrocarbon C_4H_{10}. Used in refrigeration and aerosol products.
Isopropanol	See alcohols.
JAHCS	Japan Association for Hygiene of Chlorinated Solvents
JEMA	Japan Electrical Manufacturers' Association.
JFGA	Japan Flon Gas Association.
JICOP	Japan Industrial Conference on Ozone Layer Protection.
Leadless surface	A surface mount component (SMC) whose exterior mount component consists of metallized terminations that are an integral part of the component body.
LEL	Lower Explosive Limit. The minimum concentration at which a vapour will make explosive mixtures with air.
LFF	Liquid Freon Freezant.
Lifetime	The folded-e lifetime is the time required for the quantity of a substance in the atmosphere to be reduced to 1/e (0.368) of its original quantity. The folded-e lifetime of CFC-113, for example, is about 80 years.
Liquefied gas	A low pressure propellant which at ambient temperature has a vapour pressure of less than 10 bar and will be partially liquefied inside the aerosol.
Low-solids flux	A flux which contains little solid matter, thereby reducing or eliminating the need for cleaning. See no-clean flux.
Lumen	Passage in the middle of a tube, pipe, or vessel.
MBTOC	Methyl Bromide Technical Options Committee
MDI	Medical Dose Inhalers or Metered Dose Inhalers.
MEA	Monoethanolamine.
MeBr	Methyl bromide (CH_3Br).
Metal cleaning	General cleaning or degreasing of metallic surfaces or assemblies generally with unspecified cleanliness requirements.
Methyl chloroform	See 1,1,1-trichloroethane (CH_3CCl_3) or MCF
MF	Multilateral Fund.
MF Secretariat	Secretariat to the Multilateral Fund.
MITI	Japan Ministry of International Trade and Industry.

Monoethanolamine	A saponifier capable of reacting with rosin fluxes and fatty acids. The reaction products are essentially water-soluble. Usually abbreviated as MEA.
NASA	U.S. National Aeronautics and Space Administration.
NATO	North Atlantic Treaty Organization.
NGO	Non-Government Organization.
NHLBI	U.S. National Heart, Lung, & Blood Institute.
No-clean flux	A flux whose residues do not have to be removed from an electronics assembly; therefore, no cleaning is necessary. This type of flux is often characterized by low quantities of residues.
ODP	Ozone depletion potential.
ODS	Ozone-depleting substance.
OECD	Organization for Economic Cooperation and Development.
OEWG	Open-Ended Working Group of the Parties to the Montreal Protocol.
1,1,1-trichloroethane	A hydrochlorocarbon solvent with an estimated ODP of 0.1. Also known as methyl chloroform.
OORG	Ozone Operations Resource Group.
Organic acid (OA) flux	See water-soluble flux.
Oro-pharyngeal	Appertaining to the mouth, nose, and throat.
Ozone	A gas O_3, typically formed when oxygen is ionized. Ozone partially filters certain wavelengths of UV light from the earth. Ozone is a desirable gas in the stratosphere, but it is toxic to living organisms at ground level (see volatile organic compound).
Ozone depletion	Accelerated chemical destruction of the stratospheric ozone layer. Chlorine and bromine free radicals liberated from relatively stable chlorinated, fluorinated, and brominated products by ultraviolet radiation in the ozone layer are the most depleting species.

Ozone-depletion potential	A relative index of the ability of a substance to cause ozone depletion. The reference level of 1 is assigned as an index to CFC-11 and CFC-12. If a product has an ozone-depletion potential of 0.5, a given weight of the product in the atmosphere would, in time, deplete half the ozone that the same weight of CFC-11 or CFC-12 would deplete. Ozone-depletion potentials are calculated from mathematical models which take into account factors such as the stability of the product, the rate of diffusion, the quantity of depleting atoms per molecule, and the effect of ultraviolet light and other radiation on the molecules.
Ozone layer	A layer in the stratosphere, at an altitude of approximately 10-50 km, where a relatively high concentration of ozone filters harmful ultraviolet radiation from the earth.
Ozone Secretariat	Secretariat to the Parties of the Montreal Protocol in UNEP Nairobi.
Parties	Countries that have ratified the Montreal Protocol.
Pathological	Disease state.
PCB	Printed circuit board.
PCE	Perchloroethylene.
Pentafluoropropanol	A fluorinated alcohol.
Perchloroethylene	A perhalogenated chlorocarbon solvent used extensively in industrial degreasing and dry cleaning.
Perhalogenation	An organic molecule is perhalogenated if all of the parent hydrogen atoms in a hydrocarbon are replaced with halogen atoms (astatine, bromine, chlorine, fluorine, or iodine). For example, carbon tetrachloride (CCl_4) is perchlorinated methane (CH_4). Chloroform ($CHCl_3$) is an example of a simple chlorinated methane, where only three of the hydrogen atoms have been replaced.
Perishables	Commodities that are not easy to store for more than brief periods (eg fresh fruit, vegetables, cut flowers).
PFC	Perfluorinated carbon.
Pharmacokinetics	The rates of absorption, distribution metabolism, and Pharmacodynamicsexcretion of drugs.
Photoresist	A photomechanical product, in the form of a liquid or a laminated dry film, used in the manufacture of printed circuits. Certain types of these products use large quantities of ozone-depleting hydrochlorocarbon solvents, usually 1,1,1-trichloroethane. Dichloromethane is used for stripping some types.

Precision cleaning	Cleaning of high-precision mechanical parts and electronic sensory devices, as opposed to general metal cleaning. This is usually done in "clean-rooms," with low particulate contamination, to specific standards.
Propellant	Pressurant of an aerosol which can either be a liquid or a gas inside the aerosol.
POTW	Publicly Owned Treatment Works.
Printed circuit	A printed circuit is a component for interconnecting other components. It usually consists of a metallic conductor pattern on an organic insulating substrate. After fabrication, it is known as a printed circuit board (PCB); after assembly with components it is known as a printed wiring assembly (PWA). [Terminology different in Europe and USA.]
PU	Polyurethane.
PWA	Printed wiring assembly.
Reflow soldering	A method of electronics soldering commonly used with surface mount technology, whereby typically a paste formed of solder powder and flux suspended in an organic vehicle is melted by the application of heat.
Rosin	A solid resin obtained from pine trees. It is frequently used as a flux, usually with additives.
Rosin flux	A flux whose main constituent is rosin. There are several categories of rosin flux, often designated by the codes R (pure rosin), RMA (rosin, mild activation), RA (rosin, activated usually with free chloride ions), RSA (rosin, super activated).
SA Flux	Synthetic activated fluxes.
Saponifier	A chemical designed to react with organic fatty acids, such as rosin, some oils and greases, etc., to form water-soluble soaps. This is a method for defluxing and degreasing. Saponifiers are usually alkaline and may be mineral based (sodium hydroxide or potassium hydroxide) or organic based (water solutions or monoethanolamine).
Semi-aqueous solvents	Another name for hydrocarbon/surfactant (HCS) solvents. The UNEP Committee recommends hydrocarbon/surfactant (HCS) solvents as the more descriptive and accurate nomenclature.
SMC	Surface mount component.
Solder mask (resist)	A polymeric coating applied to bare printed circuits which leaves only the pads or leads, designed to be subsequently soldered, as bare metal.

Solvent	An aqueous or organic product designed to clean a component or assembly by dissolving and/or displacing the contaminants present on its surface.
Solvent containment	Means of reducing the emission of solvents (e.g., CFCs) into the environment. This technique usually involves improving the design and operation of the equipment in which the solvent is used.
Stenched	The condition of a hydrocarbon propellant to which an odourizing agent has been added for the purpose of identifying leakage.
Steroid	A hormone with anti-inflammatory activity. Surface mount component. A component capable of being attached to a PCB using
(SMC)	surface mount technology. The component may be either leaded or leadless.
Surface mount	A technique for assembling SMCs on the surface of PCBs technology (SMT) and PWAs, as opposed to inserting leads through holes.
Surfactant	A chemical to reduce the surface tension of water. Also referred to as surface-active agents. Detergents are made primarily from surfactants.
TCA	1,1,1-trichloroethane, also known as methyl chloroform.
TCE	Trichloroethylene.
TEAP	Technology and Economic Assessment Panel.
Terpene	Any of many homocyclic hydrocarbons with the empirical formula $C_{10}H_{16}$. Turpentine is mainly a mixture of terpenes. See hydrocarbon/surfactant solvents.
Therapeutic	Treatment.
TLV	Threshold Limit Value.
TOC	Technical Options Committee.
Toxicity	The quality and degree of being poisonous.

TEWI	Total Equivalent Warming Impact. The sum of the "direct" effect of substance emissions and the "indirect" effect of carbon dioxide emissions from energy consumed in the equipment using the substance, relative to the GWP of carbon dioxide or in kg of carbon dioxide and usually expressed for 20-, 100-, and 500-year time horizons. The TEWI is calculated using a set of assumptions concerning energy source and energy conversion efficiency and lifetime, equipment energy efficiency, waste disposal, etc. and usually includes calculations of the energy "embodied" in the materials used in manufacture and disposal of the equipment.
US	United States.
UV-B	Ultraviolet Radiation type B.
Ultrasonic cleaning	Immersion cleaning where mechanical energy formed by cavitational implosions close to the surfaces being cleaned significantly aids the cleaning operation.
UNDP	United Nations Development Programme.
UNEP	United Nations Environment Programme.
UNEP IE/PAC	UNEP Industry and Environment Programme Activity Centre.
UNIDO	United Nations Industrial Development Organization.
Vapour-phase cleaning	A cleaning process, usually with CFC-113 solvent or hydrochlorocarbon solvents, where the final rinse is achieved by condensing solvent vapours on the parts being cleaned.
Vapour-phase (condensation soldering)	A method of reflow soldering where the solder and the soldering parts being joined are heated in the vapour of a perfluorinated substance whose boiling point is usually in the range of 215-260°C. In some types of equipment designed for this process, a less expensive secondary vapour blanket of CFC-113 is used.
VOC	Volatile Organic Compound.
Volatile organic compound (VOC)	These are constituents that will evaporate at their temperature of use and which, by a photochemical reaction under favorable climatic conditions, will cause atmospheric oxygen to be converted into potentially smog-promoting tropospheric ozone.*

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* Legally, some countries classify all organic substances which evaporate at ambient temperatures as VOCs, irrespective of their ozone-promoting properties.

Water-soluble flux	A flux whose post-soldering residues may be removed by a water wash. Such fluxes are usually very active, so adequate defluxing is an essential part of their use. They are also known as Organic Acid (OA) fluxes or inorganic acid fluxes.
Wave soldering	Also known as flow soldering, a method of mass soldering electronics assemblies by passing them, after fluxing, through a wave of molten solder.
WB	World Bank.
WHO	World Health Organization.
WMO	World Meteorological Organizations

Appendix G

Glossary

EPA	Environmental Protection Agency
UNEP	The United Nations Environment Programme
HTOC	Halons Technical Options Committee
NFPA	National Fire Protection Association (US)
FAA	Federal Aviation Administration (US)
CAA	Civil Aviation Authority (UK)
JAA	Joint Aviation Authority (Europe)
MOD	Ministry of Defence (UK)
UL	Underwriters Laboratories
BS	British Standard
ISO	International Standards Organization
ASTM	American Society for Testing and Materials
NATO	North Atlantic Treaty Organization
IE/PAC	Industry and the Environment - Programme Activity Centre
FIC	Fire Industry Council (UK)
HUNC	Halon Users National Consortium (UK)
HAG	Halon Alternatives Group (UK)
HARC	Halon Alternatives Research Corporation (US)
HRC	Halon Recycling Corporation
CEFIC	European Chemical Industry Council
CFPA	Conference of Fire Protection Associations (Europe)
DASCEM	Department of the Arts and Administration Services, Centre for Environment Management
ULC	Underwriters Laboratories of Canada
COP	Code of Practice
SATPH	Substitution and Transfer Plan of Halon (China)
DHB	Danish Halon Bank
MPS	Ministry of Public Security (China)
CTFHE	Comite Technique Francais Halon Environment (France)
CNPP	Centre National de Prevention et de Protection
EU	European Union
IST	The Bureau of Indian Standards (India)
DIFP	Defence Institution of Fire Research
ONGC	Oil and National Gas Commission
HRBSC	Halon Recycling and Banking Support Committee (Japan)
PFS	Polish Fire Service
SEA	Swedish Environmental Agency
FOEP	Federal Office of Environmental Protection (Switzerland)
HSG	Halon Sector Group (UK)
DTI	Department of Trade and Industry (UK)
DOT	Department of Transport (UK)
HO	Home Office (UK)
UKOOA	United Kingdom Offshore Operations Association
HSE	Health and Safety Executive (UK)
EC	European Community
RUG	Refridgerants Users Group
ANSI	American National Standards Institute

Glossary (continued)

ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
AFFF	Aqueous Film Forming Foam
CO_2	Carbon Dioxide
Halon 1211	Bromochlorodifluoromethane
Halon 1301	Bromotrifluoromethane
Halon 2402	Dibromotetrafluoromethane
HBCFs	Hydrobromofluorocarbons
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
FCs	Fluorocarbons
CAAs	Chemical Action Agent
PAAs	Physical Action Agent
LOAEL	Lowest Observed Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
ALC	Approximate Lethal Concentration
ODP	Ozone Depletion Potential
GWP	Global Warming Potential
AL	Atmospheric Life
NPS	Nuclear Protection Systems
HSSD	High Sensitivity Smoke Detection